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An Assessment of Automatic Fare Collection Equipment at Three European Transit Properties

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Final Report

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16. Abstract

This report summarizes the findings of an assessment of the performance of automatic fare collection (AFC) equipment at three European transit properties - Tyne and Wear Transport Executive, Regie Autonome des Transports Parisiens, and Stuttgarter Strassenbahnen. The properties operate in Newcastle, England; Paris, France; and Stuttgart, West Germany, respectively. Each has recently installed AFC equipment incorporating new technology - microprocessors, failure diagnostics, coin recycling, and needle printers. The analysis of the AFC equipment at each foreign property is based on a Property Evaluation Plan (PEP) that has been developed and refined by IOCs as a result of similar analyses conducted at U.S. rapid rail transit systems. The specific objectives were:

- o To apply the PEP to the three properties, in order to assess equipment performance;
- o To assess any major performance differences between similar types of equipment including equipment in use at U.S. rail transit properties; and
- o To investigate innovative equipment techniques for possible use by U.S. transit properties.

Performance results indicated that reliabilities for the European equipment were significantly greater than those for AFC equipment in-service at Port Authority Transit Corporation (PATCO), Illinois Central (ICG), Washington Metropolitan Transit Authority (WMATA), and Metropolitan Atlanta Rapid Transit Authority (MARTA).

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PREFACE

This study assesses the performance of automatic fare collection (AFC) equipment at three European properties located in Newcastle, England; Paris, France; and Stuttgart, West Germany. The U.S. DOT Transportation Systems Center (TSC) supported this study as part of continuing research in the area of automatic fare collection equipment performance and data base development. This report documents the findings of Input Output Computer Services, Inc. (IOCS) under contract number DOT-TSC-1669.

The research and documentation were performed and directed by Joseph Morrissey. Charles Erdrich, Program Manager - Analytical Services, provided technical and managerial direction. Daniel Mesnick and Andreas Tzioumis were significant contributors to the study research. In addition, Mr. Mesnick compiled several technical appendices. Joseph Koziol served as contract technical monitor. The study also relied on the contributions of many people at the transit properties. Special thanks go to John Baggs, Michael Rice, Doug Herd and Paul Ambury of Tyne and Wear Transport; Silke Bielefeld, Claus Schmidt, Alexander Wahl and Klaus Weidenbaum of Stuttgarter Strassenbahnen; and Patrice Vaintrub of Regie Autonome Des Transport Parisiens (RATP).

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

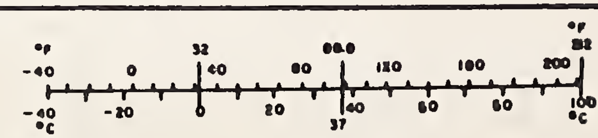

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (CONT'D)

LIST OF TABLES

LIST OF TABLES (CONT'D)

EXECUTIVE SUMMARY

An assessment of Automatic Fare Collection (AFC) equipment performance was conducted at three European properties in accordance with procedures defined in the Property Evaluation Plan developed by Input Output Computer Services, Inc. (IOCS). The properties examined were Tyne and Wear Transport Executive of Newcastle, England; Regie Autonome des Transport Parisiens (RATP) of Paris, France; and Stuttgarter Strassenbahnen (SSB) of Stuttgart, West Germany. Each assessment was based on data collected during an on-site survey, and on transaction and failure data provided by each property. Each survey was conducted during peak hours for a five-day period in July 1981.

The three properties were selected in part because each has recently installed equipment incorporating microprocessor technology, needle printers, and coin recycling. The assessment is part of the Rail Transit Fare Collection (RTFC) project being conducted under the sponsorship of the Urban Mass Transportation Administration (UMTA) by the Transportation Systems Center (TSC). The UMTA RTFC project has identified a critical need for U.S. transit systems to develop improved AFC systems in order to improve operating efficiency, enhance control of receipts, increase the rate of passenger flow, and reduce labor and maintenance costs.

The objectives of the current study were threefold:

1. To apply the IOCS Property Evaluation Plan to the three properties in order to assess AFC equipment performance;

2. To assess any major performance differences between similar types of equipment including equipment in use at U.S. rail transit properties; and

3. To investigate innovative equipment techniques for possible use by U.S. transit properties.

TYNE AND WEAR METRO

Transit and AFC System

The Tyne and Wear Metro serves approximately 1.2 million people in Newcastle, England and surrounding communities with an integrated bus and rapid rail system. The Metro rail system opened in the summer of 1980 and will encompass 34 miles and have 41 stations when completed in 1983. Currently, 14 miles and 18 stations are open, serving a weekly ridership of 180,000. Fares are based on the number of zones travelled.

The AFC system consists of 68 self-service vendors, 30 booking office machines, and 89 passenger entry gates, of which 29 are fully accessible gates designed for handicapped passengers. The vendors and booking office machines were manufactured by Crouzet of France. The cabinets and mechanical barriers of the gates were built by Cubic-Tiltman Langley and the microprocessor-controlled magnetic ticket readers were manufactured by Crouzet.

The Tyne and Wear vendor incorporates a reprogrammable microprocessor, failure diagnostics, needlepoint printer, and coin recycling subsystem. The machine accepts only coins and dispenses single magnetically encoded one-trip paper tickets of the Edmondson size (1-3/16" x 2-5/8"). The automatic gates can accept the tickets inserted in any of four possible orientations.

Equipment Performance - On-Site Data (IOCS Survey)

Table 1 summarizes the reliabilities computed for Tyne and Wear vendors. The reliability of a sample of 19 vendors was

TABLE 1. SUMMARY OF TYNE AND WEAR VENDOR RELIABILITIES

PERIOD	NO. OF VENDORS	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)
IOCS Survey July 13-17, 1981	19	.999789	4,708	14,123
Property-Supplied Data				
April 1981	53	.999859	7,087	503,169
May 1981	65	.999830	5,882	647,021
May 1981*	53	.999954	6,757	567,612
April-May, 1981*	53	.999855	6,908	1,070,781

*Excludes data on vendors at four new stations.

measured at 4,708 mean transactions per failure (MTF), based on more than 14,000 tickets vended. Mean time between failures (MTBF) was measured at 71.7 hours.

The reliability of a sample of 16 gates was measured at 10,299 MTF based on more than 20,000 entries. MTBF was 91.1 hours.

Availability measures were also generated based on the on-site data. Vendor availability was 99.6 percent, based on more than 215 hours of machine operation. For the gates, availability was 99.8 percent, based on more than 182 machine hours.

Maintainability measures were also generated for the surveyed equipment. For both the vendors and gates, the average downtime was 13 minutes. For the vendors, the average time to repair was nine minutes; for the gates it was three minutes. Note that these figures represent repair on "soft" or minor failures. "Hard" or major failures did not occur at the machines during the survey period, preventing the computation of significant maintainability measures.

Property-Supplied Data

Reliability was also measured for vendors and their magnetic ticket issuer/reader subsystem, based on transaction and failure data provided by the property. The data were from April and May 1981. The system total reliability in April was 7,087 MTF while, for May, the MTF measure was 5,882. The May figure included the performance of vendors at four new stations. When these machines were excluded, the May vendor reliability was 6,757 MTF, a five percent decline that was not

statistically significant*. When the April and May figures were combined and the vendors at the new stations not considered, the reliability was 6,908 MTF, based on over one million tickets sold.

For the magnetic ticket issuer/reader subsystem, the April reliability was 14,799 MTF for the 53 vendors in the Metro system. For the same machines, the May reliability was 13,844 MTF, a seven percent decline that was not statistically significant. For the 53 vendors, the two-month MTF measure for this subsystem was 14,277.

An analysis of failure data was undertaken in an effort to explain and highlight the performance of the equipment. On-site survey failures were few. The four vendor failures that did occur included two ticket jams, a coin jam in the recycling subsystem, and a clock with incorrect time. Only two failures occurred at the gates. One resulted from dirt and ticket dust accumulating around a sensor in the ticket reader. The other was a ticket jam in the reader.

In addition to these failures, the failure data provided by the property were examined and distributions generated. The distribution of 155 vendor failures for April and May by major subsystem affected was as follows: magnetic ticket issuer/reader (48 percent), coin recycling subsystem (25 percent), coin selector (10 percent), and logic (three percent).

A further analysis revealed that 63 percent of the magnetic ticket issuer/reader failures were photosensors that did not change state, i.e., reset, after delivery of a ticket. Twenty-five percent of the failures were related to the new strip feed contact, a component that facilitates changing over

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*All statistical tests were performed at the 95 percent confidence level. For details on the tests, refer to Section 5.2.

to a new roll of paper. For the coin recycling subsystem, failures were distributed over nine subcategories. The subcategory with the largest percentage of failures was the condition wherein coins were viewed by the selector, but not viewed by the recycling cassette (about 20 percent). Approximately 80 percent of the coin selector failures were selectors that were jammed or stuck. Logic failures were not detailed as to the cause, but in one case, a central processing unit was replaced.

The performance of individual stations found to have vendor reliabilities significantly below the system totals for each month was examined and discussed. For these stations, reliabilities of individual vendors were examined as a means to identify problem equipment.

STUTTGARTER STRASSENBAHNEN

Transit and AFC System

Stuttgarter Strassenbahnen (SSB) operates an extensive trolley and bus system serving approximately two million people in Stuttgart, West Germany and its surrounding communities. The SSB system comprises 10 trolley lines with 400 trolleys and 60 bus lines with 300 buses. Ridership on the SSB is approximately 400,000 per workday. Fares are based on the number of zones travelled. An honor system is used whereby passengers are responsible for their own ticketing, and access to and from the system is not controlled except by random inspection.

The AFC system consists of approximately 490 self-service vendors, and ticket cancellers. The vendors dispense individual single-ride and multi-ride tickets. The vendors are located at every trolley stop and at high passenger volume bus stops. The cancellers are located on each vehicle for use with the multi-ride tickets.

The vendors were manufactured by Autelca of Switzerland. Similar to the Tyne and Wear vendors, the machines incorporate a reprogrammable microprocessor, failure diagnostics, needlepoint printer, and coin recycling. The machine accepts only coins and dispenses tickets that are not magnetically encoded.

Equipment Performance - On-Site Data

Table 2 summarizes the reliabilities computed for SSB vendors. The reliability of a sample of ten vendors was measured at 1,821, based on more than 5,000 tickets vended. MTBF was measured at 45.3 hours. Availability of the equipment during the survey was almost 100 percent, based on 136 machine hours of operation.

Equipment Performance - Property-Supplied Data

Extensive transaction and failure data were provided by the property. These data were provided for the ten surveyed machines for the entire survey week. In addition, six-month transaction and failure data in the form of maintenance records were provided for 16 machines located inside at the system's central station, and for six machines located at outdoor stops. The data were used to compare the performance of indoor and outdoor equipment. The major piece of data provided by the property was a summary of eighteen months of transaction and failure data for the entire system.

Full Survey Week

The reliability for the ten surveyed machines for the week of July 27-July 31 was 2,711 MTF, based on over 16,000 transactions. Failures for the ten machines during the full survey week included a defective cable, faulty printer, and a coin jammed in a recycling disc. Average time to repair was 11 minutes per failure.

TABLE 2. SUMMARY OF SSB VENDOR RELIABILITIES

PERIOD	NO. OF VENDORS	RELIABILITY R	MTF	SAMPLE SIZE	COMMENT
Survey July 27-31, 1981	10	.999451	1,821	5,464	
Full Week July 27-31, 1981	10	.999631	2,711	16,265	This & the following MTFs based on property-supplied data
1980	489	.999929	14,042	15,544,955	Technical failures only
Jan-Jun 1981	485	.999921	12,728	7,344,284	Technical failures only
Jan-Jun 1981	485	.999698	3,311	7,344,284	All failures
Jan-Jun 1981	485	.999761	4,178	7,344,284	Excluding vandal & administrative failures
Jan-Jun 1981	485	.999856	6,948	7,344,284	Technical plus selected other failures (e.g., plugs and cables)

The reliability of the 16 indoor vendors for the six-month period January-June 1981, was 21,214 MTF. The reliability of the six outdoor vendors was 14,593 MTF. A statistical test indicated that the difference was not significant. For the indoor and outdoor comparison, an examination of failure distributions revealed that they were similar except for the absence of coin disc failures in the outdoor machines. For each group, printer failures represented about half of all failures.

Reliability for the entire SSB system for 1980, based only on technical failures, was 14,042 MTF. Tickets vended exceeded 15 million. In the first six months of 1981, the system-wide MTF measure, based on technical failures, was 12,728. For the same period in 1980, the MTF measure was 13,080. The 10 percent decline was not found to be statistically significant.

A series of system-wide reliability measures for the first six months of 1981 were generated, based on various categories of failures. The MTF's ranged from 3,311, based on all failures (including vandal-related), to 6,948, based on technical failures plus failures to peripheral equipment, such as plugs and cables. In addition to these vendor reliabilities, the reliability of the needlepoint printer was measured at 32,497 MTF.

With respect to the system-wide reliability measures, failure distributions were examined in an effort to explain monthly variations. In addition, technical failures for the first six months of 1981 were presented by subsystem or component affected. The hierarchy of the 577 technical failures by major subsystem was: needlepoint printer (39 percent) coin guiding plate (16 percent) coin recycling discs (14 percent), coin acceptor (nine percent) and logic (six percent).

REGIE AUTONOME DES TRANSPORTS PARISIENS (RATP)

Transit and AFC System

The RATP operates an extensive and integrated bus and rail system serving approximately eight million people in Paris, France and its suburbs. The rail system is comprised of two coordinated rail networks: the urban Metro and the RER (Regional Rapid Transit) commuter line. The rail system transports about 4.8 million people per workday, four million of whom ride the Metro.

The Metro comprises 13 main lines and two short feeder lines. The system covers 188.9 kilometers (118 miles) and has 358 stations spaced an average of about 540 meters apart. The RATP RER consists of two lines having 63 stations, covering 100 kilometers (62 miles). Stations are spaced an average of two kilometers apart. The RATP employs a flat fare on the Metro and a zone fare on the RER.

The RATP AFC system is actually two systems - one each for the Metro and RER. Each system is controlled by a central computer. The systems are coordinated so that a passenger can enter or exit from either without requiring another ticket.

The Metro system consists of about 360 agent-operated ticket issuing machines, known as ADARs (French acronym), and 1,700 entry gates. The AFC system was designed and manufactured by a consortium of the following companies: CGA, SESA, CAMP and Marcel Dassault. The ADARs distribute a variety of tickets and passes of the Edmondson size, the most popular being the Orange Card (Carte Orange) which is used by 60 percent of the rail system passengers during peak hours. The gates provide for entry control and accept tickets in any of four orientations, similar to the Tyne and Wear gate.

The RER AFC system consists of 370 self-service vendors, 50 agent-operated vendors, and about 540 automatic gates. Of these, 170 are entry-only, 310 are exit-only, and 60 are reversible. Each piece of equipment is connected to a computer located in the station. The system was designed and manufactured by Crouzet with the collaboration of CGA and CAMP. Beginning in 1980, RATP has been installing microprocessor-controlled Crouzet gates. There are currently about 270 in-service and about 120 on order.

The vendors in-service were manufactured by Crouzet and installed in 1969. They incorporate six coin acceptors with a recycling change subsystem consisting of stack storage units, located directly beneath each acceptor. The machines accept only coins and vend magnetically encoded individual and carnets (groups of ten) of single-trip tickets. Between 1970 and 1980, the vendors had 10 French Franc bill acceptors that were discontinued because of fraud and unreliability.

In an effort to replace these machines, RATP has been experimenting with microprocessor-controlled vendors from Crouzet and Marcel Dassault. The replacement program is scheduled to begin in 1984.

The new Crouzet vendor is similar to the Tyne and Wear vendor. The Dassault vendor incorporates the Autelca coin recycling subsystem used in the SSB machines. The machine has a large display for communication with patrons. It is programmed to display information in English and German as well as in French.

Equipment Performance - On-Site Data

Reliability measures for the 13 vendors and 57 gates surveyed were not able to be generated due to a failure of the RATP computer system to provide transaction data. Reliability

estimates were provided by RATP officials in terms of mean transactions per maintenance action for the Metro and RER gates. The Metro gates were experiencing a reliability of roughly 50,000. The RER Crouzet gates had an initial reliability of 20,000 and were experiencing an average of about 60,000. Note that these figures do not include ticket jams cleared by station agents.

Availability for the surveyed vendors was measured at 88.5 percent, based on 88 hours of machine operation. For the gates, availability was 98.0 percent, based on over 288 hours of machine operation.

No failures were observed for the surveyed vendors, although several failures occurred during non-survey periods that left the equipment out-of-service for long periods during the survey. Failures occurring at the Metro gates included a hard failure of a tripod and several ticket jams. Repair of the tripod took over an hour. For the RER Crouzet gates, a hard failure occurred that required the removal of a printed circuit board. Active repair time was 40 minutes. The most common problem observed with both the Metro and RER gates was the intermittent nonacceptance of tickets.

COMPARISON WITH EQUIPMENT USED AT U.S. TRANSIT PROPERTIES

The performance of the AFC equipment at Tyne and Wear and SSB were statistically compared to the performance of similar equipment in-service at American transit properties. The American properties used in the comparison included Port Authority Transit Corporation (PATCO), Illinois Central Gulf (ICG), Washington Metropolitan Area Transit Authority (WMATA), and Metropolitan Atlanta Rapid Transit Authority (MARTA). Comparisons were made on the basis of the type of data used to generate the measures. In other words, reliability figures based on data collected during on-site surveys were analyzed

separately from those based on maintenance or failure records provided by the properties. Where significant differences in performance were found, failure distributions were examined in an effort to explain the differences. (The impact of maintenance on performance differences is discussed in the next section.) Failures that were related to bill acceptors were not included in the assessment since the European machines do not incorporate the devices.

For the vendors, based on the on-site data, both the Tyne and Wear and SSB machines had MTF measures significantly greater than those for ICG and WMATA at the 95 percent confidence level. As can be seen in Table 3, the WMATA measures included the reliabilities measured for two retrofit programs. An examination of performance differences based on failure data was not possible due to the low number of failures that occurred in the European machines.

The comparison based on property-supplied data had similar results. Both Tyne and Wear and SSB vendors had MTFs significantly greater than those for PATCO and ICG at the 95 percent confidence level (Table 4). An examination of failure distributions did not adequately explain the differences,i.e., failure distributions were similar.

For automatic gates, the comparison was based only on the on-site data since property data for the Tyne and Wear gates were not available. The reliability for the Tyne and Wear sample was significantly greater than that for both the MARTA and WMATA gates, both pre- and post-retrofit (Table 5). Note that the MARTA gates accept coins, tokens and farecards. Even when coin acceptor failures were not included in the reliability computation, the reliability of the MARTA gates was still significantly less than that of the Tyne and Wear gates at the 95 percent confidence level. The performance of the European gates was also greater than that of the ICG gates.

TABLE 3. COMPARISON OF VENDOR RELIABILITIES BASED ON ON-SITE DATA

PROPERTY	NO. OF VENDORS	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
Tyne & Wear	19	.999789	4,708	14,123	3
SSB	10	.999451	1,821	5,464	3
ICG	9	.996613	295	5,019	17
WMATA (Pre-Retrofit)	40	.993759	160	153,983	961
WMATA (Retrofit A)	14	.994282	175	20,638	118
WMATA (Retrofit B)	6	.997630	422	20,673	49

TABLE 4. COMPARISON OF VENDOR RELIABILITIES BASED ON PROPERTY-SUPPLIED DATA

PROPERTY	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
Tyne & Wear	.999855	6,908	1,070,781	155
SSB	.999761	4,178	7,344,284	1,758
PATCO	.996846	317	97,960	309
ICG	.992074	126	10,976	87

TABLE 5. COMPARISON OF AUTOMATIC GATE RELIABILITIES BASED ON ON-SITE DATA

PROPERTY	NUMBER OF GATES	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
Tyne & Wear	16	.999903	10,299	20,597	2
ICG	28	.999781	4,570	86,842	19
WMATA (Pre-Retrofit	24	.998007	502	191,696	382
WMATA (Retrofit A)	18	.998592	712	134,268	189
WMATA (Retrofit B)	7	.999551	2,220	153,600	69
MARTA*	26	.999425	1,740	106,122	61
MARTA**	26	.999588	2,427	80,099	33
CTA***	14	.998893	904	17,170	19
MBTA***	30	.999358	1,558	46,740	30
PATH***	31	.999497	1,989	137,239	69

*Overall machine reliability.

**Reliablity excluding coin acceptor transactions and failures.

***Turnstiles that incorporate coin (or token) acceptors, but not ticket transports. Shown for comparison.

However, the difference was not found to be statistically significant.

The performance measures for gates at other American transit systems are shown in Table 5 for reference. It is important to note that CTA, MBTA, and PATH gates do not have ticket transports. Nevertheless, the reliability of the Tyne and Wear sample was significantly greater than that of each property sample.

Maintenance

This section presents summary descriptions of the maintenance organizations of the three European properties and two American properties, PATCO and ICG. In addition, the impact of maintenance on the performance differences between the European and American equipment is discussed.

At Tyne and Wear maintenance for both the vendors and the gates is provided by a subcontractor. As part of the original contract with Crouzet, Tyne and Wear was provided a one-year equipment warranty. Crouzet subcontracted Balfour-Kilpatrick Inc. to provide the maintenance/warranty service.

The AFC maintenance organization comprises six electronic technicians, two engineers, i.e., senior technicians, and a supervisor. Under a program initiated by Tyne and Wear, three of the technicians are Metro employees, who are being trained to repair equipment coming out of warranty.

Maintenance is divided into two levels. The first is on-site correction and routine preventive maintenance. The latter is carried out on gates and vendors about every six weeks, in accordance with an extensive checklist of items to be attended (see Appendix C). The second level consists of repairs and overhauls in the workshop.

When a gate or vendor goes out of service, a control center is automatically notified via a computerized Remote Control Indicator (RCI) system. The message sent to the center indicates whether the out-of-service condition is due to a technical failure, a full vault, or ticket stock. If due to a technical failure, a supervisor at the center informs a maintenance technician in the field by a two-way radio.

The SSB AFC maintenance organization comprises 25 technical and maintenance support personnel located at a central workshop. During the day, there is a team of two technicians in the field who are in radio contact with the central facility. Since the machines are not monitored electronically, patrons and drivers are relied upon for information on out-of-service vendors.

In the field, the technicians make necessary minor adjustments, e.g., cleaning paper jams in the printer or removing bent coins. In addition, for preventive maintenance and major repair, the technicians replace components and subsystems and bring them back to the central workshop where more highly skilled personnel attend to the equipment. Several of the major subsystems, such as the printer, coin acceptor, and coin recycler, are replaced and preventively maintained about once a year (see Appendix F). However, machines that experience extensive use usually have the printer replaced every six months.

At RATP, each rail system has its own AFC maintenance organization. The Metro has a centralized organization based around a main workshop, while RER has a decentralized organization comprised of small workshops located at various stations.

The Metro AFC maintenance organization consists of about 45 technicians and their supervisors. There are separate

groups for preventive maintenance and equipment repair. These groups are futher subdivided by equipment type. Preventive maintenance is carried out on the gates about once every 4-5 weeks, and on the ADARs about once every 5-12 weeks, depending on ticket volume.

For major failures, i.e., those not able to be fixed by a station agent, a technician is contacted via two-way radio by a central dispatcher. Major repairs are, if possible, done on-site, with workshop technicians primarily used for overhaul of major components as part of the preventive maintenance program.

The RER AFC maintenance organization consists of about 40 technicians and their supervisors. The technicians each cover an assigned area of two to three stations. RER AFC technicians can do preventive maintenance and repair on all types of AFC equipment. When a failure occurs that a station agent cannot fix, the station master contacts the appropriate maintenance workshop.

Gates in the RER are preventively maintained once every 7-8 weeks. For vendors, the period is 3-12 weeks depending on ticket volume. The experimental vendors have been preventively maintained on a 6-8 week basis.

The PACTO AFC maintenance organization consists of ten people: a foreman, eight electronic technicians and one repair man. On weekdays during the daytime hours (including both morning and evening peak periods), there are two technicians in the field responding to calls for repair from an operator in a monitoring center. One technician covers the Pennsylvania side, the other the New Jersey side of the system. The operator receives patron complaints and information concerning AFC equipment problems and contacts the appropriate technician. The technicians do repair work only. When

finished with a job, they call the operator to let it be known that the repair has been done, and to inquire about another job. In some cases, these technicians will find and repair unreported failures.

In addition to the field technicians, the foreman, two electronic technicians and the repair man work at a central shop facility. One of the technicians and the repair man do preventive maintenance and overhaul. The second technician does component repair, primarily on electronics and coin acceptors. At PATCO, vendors are not preventively maintained but are attended on a repair basis. Gates, on the other hand, are preventively maintained on a fixed schedule by component. For example, the ticket handler is maintained once per year.

The ICG AFC maintenance organization consists of 29 persons, two of whom are supervisors. This number includes a group of six field electronic technicians responsible for the upkeep of the PAL (Passenger Assistance Line) equipment. (The PAL is a central monitoring facility providing patron assistance, closed circuit television and public address system.) Another group of four electronic technicians work at the central workshop and do equipment rebuilding, redesign and modification under a research and development program.

The remaining personnel provide repair and preventive maintenance of vendors and gates, and are assigned into one of four coverage areas, each with its own small shop.

On weekdays during daytime hours (including both morning and evening peak periods), there are either one or two electronic technicians covering each area. These workers are contacted by PAL operators who inform them of equipment problems. After each repair, technicians fill out Trouble Logs indicating the type of failure repaired. If not working on a repair, the technicians are preventively maintaining the

groups for preventive maintenance and equipment repair. These groups are futher subdivided by equipment type. Preventive maintenance is carried out on the gates about once every 4-5 weeks, and on the ADARs about once every 5-12 weeks, depending on ticket volume.

For major failures, i.e., those not able to be fixed by a station agent, a technician is contacted via two-way radio by a central dispatcher. Major repairs are, if possible, done on-site, with workshop technicians primarily used for overhaul of major components as part of the preventive maintenance program.

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equipment. (Gates and vendors are preventively maintained about once a week.) In rare instances where a bench is required, the technicians will bring a part back to a shop for repair.

At the central maintenance facility there are three electronic technicians assigned to do simple electrical and mechanical repairs. Sometimes these workers are dispatched to the field to handle additional workload.

Maintenance and Performance

The impact of maintenance on the performance differences between the European and American equipment was considered. The components of maintenance described above, i.e., policy, organization and technique, certainly affect equipment performance. However, with respect to reliability, this effect is difficult to quantitatively assess because of several factors, such as the type, generation and mix of equipment in-service, and technician skill levels and workloads.

These considerations notwithstanding, a rough estimate of level of effort can be generated based on equipment per maintenance personnel measures. These have been generated for Tyne and Wear, SSB, PATCO and ICG, and are presented in Table 6 with corresponding reliability measures. (Note that the vendor MTFs are based on property data, the gate MTFs, with the exception of the PATCO figure, are based on on-site data. The PATCO gate reliability is shown for reference, and, in any case, would be higher than a reliability based on on-site data.)

As can be seen in Table 6, SSB and Tyne and Wear have higher equipment per maintenance personnel ratios, i.e., technicians and repairmen cover more machines, yet the reliabilities of the equipment were higher than both PATCO and ICG. (Significantly higher in the case of the vendors, not

TABLE 6. COMPARISON OF EUROPEAN AND AMERICAN AFC EQUIPMENT PERFORMANCE AND MAINTENANCE WORKLOADS

PROPERTY	VENDORS	VENDOR MTF*	NO. OF GATES	GATE MTF**	NO. OF AFC MAINTENANCE PERSONNEL	AFC EQUIPMENT/ WORKER
T&W	65	6,908	89	10,299	9	17.1
SSB	485	4,178	N/A	N/A	25	19.4
PATCO	61	317	75	5,907	10	13.6
ICG	112	126	169	4,570	19	14.8

*MTFs based on property data.
N/A = Not applicable.
**MTFs based on on-site data (except PATCO)

significantly higher for the gates.) However, it is not possible, based on such limited data and the cautions presented above, to infer with any statistical confidence the predominant reason(s) for this anomalous situation. In other words, it is just as likely that the significantly greater performance of the European equipment is due to equipment characteristics (state-of-the-art) than to maintenance level of effort, technique, organization or policy. Common sense suggests that a mix of the factors are responsible, but isolating any of these is not possible based on limited data.

APPLICATION TO U.S. PROPERTIES

The application of the European equipment to the U.S. transit environment was assessed, based on the perceived advantages and disadvantages of the equipment. It is suggested that the coin recycling and microprocessor technology found in the Tyne and Wear, RATP and SSB vendors could enhance unmanned station operation, and improve failure identification, repair productivity and control of accounting data.

With a coin recyclying system, the vendors do not have to be regularly filled with coins as do the ICG vendors. Coupled with a high-capacity vault subsystem, this allows for longer periods of service without opening the machine.

The microprocessor technology provides capability in a number of areas: reprogramming of fares, failure diagnostics, and control of accounting data. Reprogramming of fares can be done quickly with the insertion of a new program in the logic. The program can be placed in the machine and set to trigger fare changes automatically on a given date.

The failure diagnostic capability provides quick indication of the type of failure. This could enhance the productivity of equipment repairs since technicians would not have to spend

much time isolating the problem. In addition, failure diagnostics can improve the recording of failures by providing technicians with clearly assignable failure categories.

For the accounting function, the machines can maintain an extensive array of accounting data for long periods, or be programmed to deliver data to a central computer. If the latter capability is utilized, as it is in the RATP system, machine openings can be limited to vault pickups, ticket stock refills, and necessary maintenance actions.

For the first-generation American AFC systems such as ICG and PATCO, the coin recycling and microprocessor technology could enhance system operation and efficiency. However, use of vendors such as those in service at Tyne and Wear, requires the use of gates that accept the Edmondson size tickets. (PATCO, WMATA, ICG and MARTA use farecards of the credit-card size.)

The Tyne and Wear gates are microprocessor-controlled and linked to a central monitoring facility. The gates are used for entry control and are designed to read, write, and cancel. They incorporate failure diagnostics and a revolving paddle-like barrier. The failure diagnostic capability could potentially enhance failure identification and repair productivity at U.S. transit properties.

Similar gates in-service at RATP are configured to read, write, verify and, if necessary, capture. Many of the 250 RATP gates operate in both directions, similar to gates at PATCO, ICG and WMATA. In addition, the RATP gates are linked to a central computer that transmits appropriate commands for gate operation and controls accounting receipts.

1. INTRODUCTION

This report presents the findings of an assessment of the performance of the automatic fare collection (AFC) equipment in-service at three European transit properties - Tyne and Wear Transport Executive, Regie Autonome des Transports Parisiens (RATP), and Stuttgarter Strassenbahnen (SSB). The properties operate in Newcastle, England; Paris, France; and Stuttgart, West Germany, respectively. Each assessment was based on data collected during an on-site survey, and on transaction and failure data provided by each property. Each survey was conducted during peak hours for a five-day period in July, 1981.

This study is part of an on-going analysis of AFC equipment that is being conducted under the sponsorship of the Urban Mass Transportation Administration (UMTA) by the Transportation Systems Center (TSC) as part of the Rail Transit Fare Collection (RTFC) Project. The analysis of the AFC equipment at each foreign property is based on a Property Evaluation Plan that has been developed and refined by IOCS as a result of similar analyses conducted at U.S. rapid rail transit systems.

1.1 PURPOSE AND OBJECTIVES

The UMTA RTFC project has identified a critical need for U.S. transit systems to develop improved AFC systems in order to improve operating efficiency, enhance control of receipts, increase the rate of passenger flow, and reduce labor and maintenance costs. In order to achieve the goals of the project, an extensive research and development program has been undertaken. Under this program, a uniform methodology has been developed to assess the performance of existing AFC systems.

These assessments will lead to the development of a set of industry-wide performance guidelines and specifications for AFC equipment that will help properties make decisions in selecting equipment.

AFC systems have been in operation in many European cities since the 1960's. Cities such as Paris and London operate highly sophisticated AFC systems. In addition, equipment incorporating microprocessor and other technology has been recently installed at properties such as Tyne and Wear, RATP and SSB. In order to enhance the analysis of current AFC systems, these three European transit properties were chosen for assessment using the IOCS Property Evaluation Plan (PEP). The specific objectives of the study were:

1) To apply the PEP to the three properties, in order to assess AFC equipment performance;

2) To assess any major performance differences between similar types of equipment including equipment in use at U.S. rail transit properties; and

3) To investigate innovative equipment techniques for possible use by U.S. transit properties.

1.2 REPORT ORGANIZATION

Each property and its AFC equipment are described in separate sections (Sections 2-4). In these sections, information on the AFC systems consists of general descriptions of major equipment subsystems. (Maintenance organization and general practices are described in Section 6 as mentioned below.) Details of equipment design and operation, listings of modifications made to the equipment, and detailed maintenance procedures are contained in the appendices to the report. It

is important to note that each appendix reflects the level of information that the property was able to provide. For example, RATP was not able to provide detailed design or technical descriptions for some of its vendors. SSB was not able to furnish detailed maintenance procedures, but allowed IOCS surveyors to observe replacement and minor repair of equipment in the field.

Section 5 of the report describes the data collection plan and presents the performance measures computed from the data. The results vary from property to property because each provided different levels of data. For example, Tyne and Wear provided mean transaction per failure (MTF) figures for each vendor for April and May 1981. SSB was able to provide monthly reliability measures for the system taken as a whole. In addition, SSB provided monthly transaction and failure data on specific machines.

The analysis of the performance data is presented in Section 6. Included are failure distributions constructed using both the survey data and the data provided by the properties. In addition, Section 6 contains a comparative analysis of the performance of the European machines with similar equipment in service at U.S. properties. As part of this analysis, descriptions of the maintenance organization and practices of the European properties and selected U.S. properties are presented. Section 6 also addresses the application of the European equipment to the U.S. transit AFC experience.

2. TYNE AND WEAR TRANSPORT EXECUTIVE

2.1 TRANSIT SYSTEM

The Tyne and Wear Transport Executive serves approximately 1.2 million people in Newcastle Upon Tyne, England, and surrounding communities with an integrated bus and rapid rail transit system. The 1,300-bus operation has an annual ridership of about 288 million and employs almost 6,000 people. The new rapid rail system, the Metro, opened in Summer 1980 and will encompass 55 kilometers (34 miles) and 41 stations when completed in 1983. Currently, 23 kilometers (14 miles) and 18 stations are open, serving a weekly ridership of 180,000. The current 22 articulated car,11 train fleet will grow to a peak service requirement of 88,84-seat cars by the completion date.

The Metro has unmanned stations and employs about 500 people. Closed-circuit television (CCTV) and public address systems have been provided; however, the CCTV system is currently only in-service at major stations. The system was designed to be fully accessible to the handicapped. Approximately 40 percent of the bus and rail operating budget is subsidized by local government, which, in turn, receives a proportion of this subsidy from the central government.

Figure 2-1 shows the current and planned rail system. Currently, two lines, sharing a common Northbound track from Haymarket Station in Newcastle center, branch West and East at South Gosforth to Bank Foot and Tynemouth, respectively. The travel time from Haymarket to Tynemouth is approximately 22 minutes. When completed, two additional lines will provide coverage along the North and South sides of the River Tyne, and will have transfer points with British Rail at two locations.

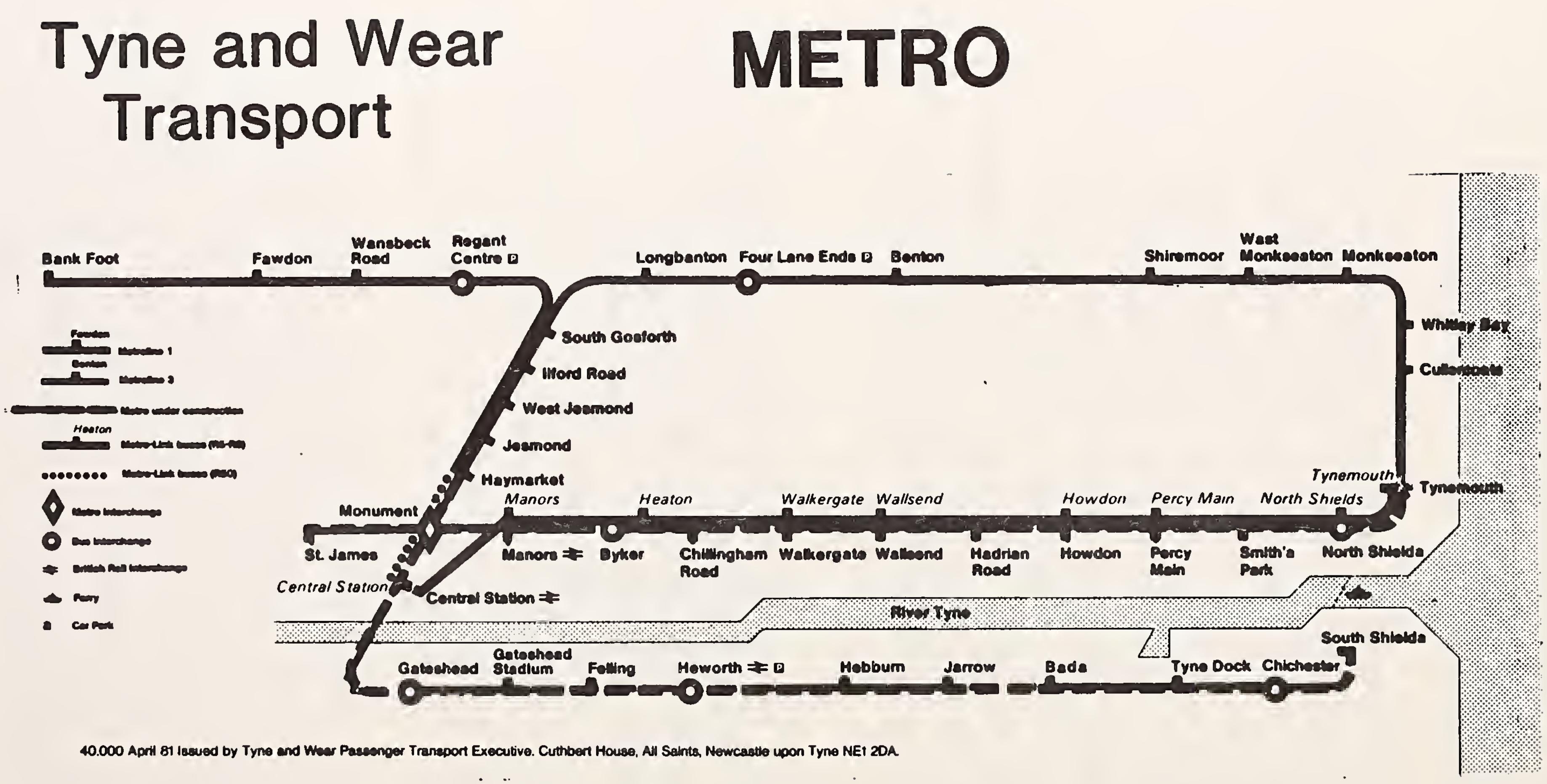

FIGURE 2-1. TYNE AND WEAR TRANSPORT RAIL TRANSIT SYSTEM

Tyne and Wear Transport has a complex zonal fare structure for both bus and rail with pre-encoded transfer tickets (called Transfare) available on certain buses for transfer to the Metro. Fares currently range from a minimum, one-stage, eight pence fare to a maximum of 38 pence (about 17 cents to 80 cents). The fare media on the rail system are magnetically encoded single-ride tickets or multi-use passes (called Traveltickets). Single-ride reduced and full fare tickets of the Edmondson size (1-3/16" x 2-5/8") are purchased from self-service automatic vendors that accept five different coin types and give change. A variety of weekly, four-week, off-peak, and all-day passes are dispensed by agent-operated booking office machines. Each Travelticket purchaser is issued a pass holder and an ID photo. Reduced fare tickets are available for children and some students. The elderly and disabled can ride at no charge during the offpeak, and if they work, they are also granted free travel during peak hours. Currently, 55 percent of Metro riders use passes; 30 percent use passes system-wide (bus and rail).

Entrance to the Metro is controlled via automatic gates that accept the encoded tickets and passes. Exit is via exit-only gates that freewheel in the exit direction. In addition, fully accessible gates are provided for the handicapped for both entry and exit. A force of 30 mobile inspectors randomly checks passengers to ensure that the proper fare is being paid. A penalty of two pounds (four dollars) is imposed on the spot for fare evasion. Fraud has thus far been negligible.

2.2 AFC SYSTEM

The Tyne and Wear Metro AFC system consists of 68 self-service vendors, 30 booking office machines, and 89 passenger entry gates, of which 29 are fully accessible gates designed

for handicapped passengers. When the entire system is completed, there will be 118 vendors and 250 gates. The vendors and booking office machines are manufactured by Crouzet. The cabinets and mechanical barriers of the gates are manufactured by Cubic-Tiltman Langley and the ticket transports are manufactured by Crouzet.

Each piece of AFC equipment is connected to a control center that electronically monitors when a machine goes out of service or is opened illegally, and when a vendor needs a new roll of paper or has a full cash box. When failures do occur, maintenance personnel are informed via two-way radio from the control center. Currently two stations are monitored by closed circuit televisions from the control center. Tyne and Wear plans to eventually monitor all stations.

The following sections describe the general operation of the vendors and the gates used in the Tyne and Wear Metro. As mentioned above, the details of the operation of the equipment, modifications made to the equipment, and maintenance procedures are contained in Appendices A, B and C, respectively.

2.2.1 Vendors

The 68 vendors in-service at Tyne and Wear Metro are located in station mezzanines. The machines accept five different types of coins, give change, and issue magnetically encoded single one-trip paper tickets from blank roll stock. Both reduced and full fare, i.e., adult, tickets are vended. The vendors use microprocessor technology and include a recycling change subsystem. If they run out of change, they automatically go into exact change mode. In addition, they will accept overpayment of up to 19 pence (19P) in the exact change mode. They have two cash boxes which are monitored by the number and type of coins that are in them. Figure 2-2 shows the vendor and Figure 2-3 shows the adult ticket.

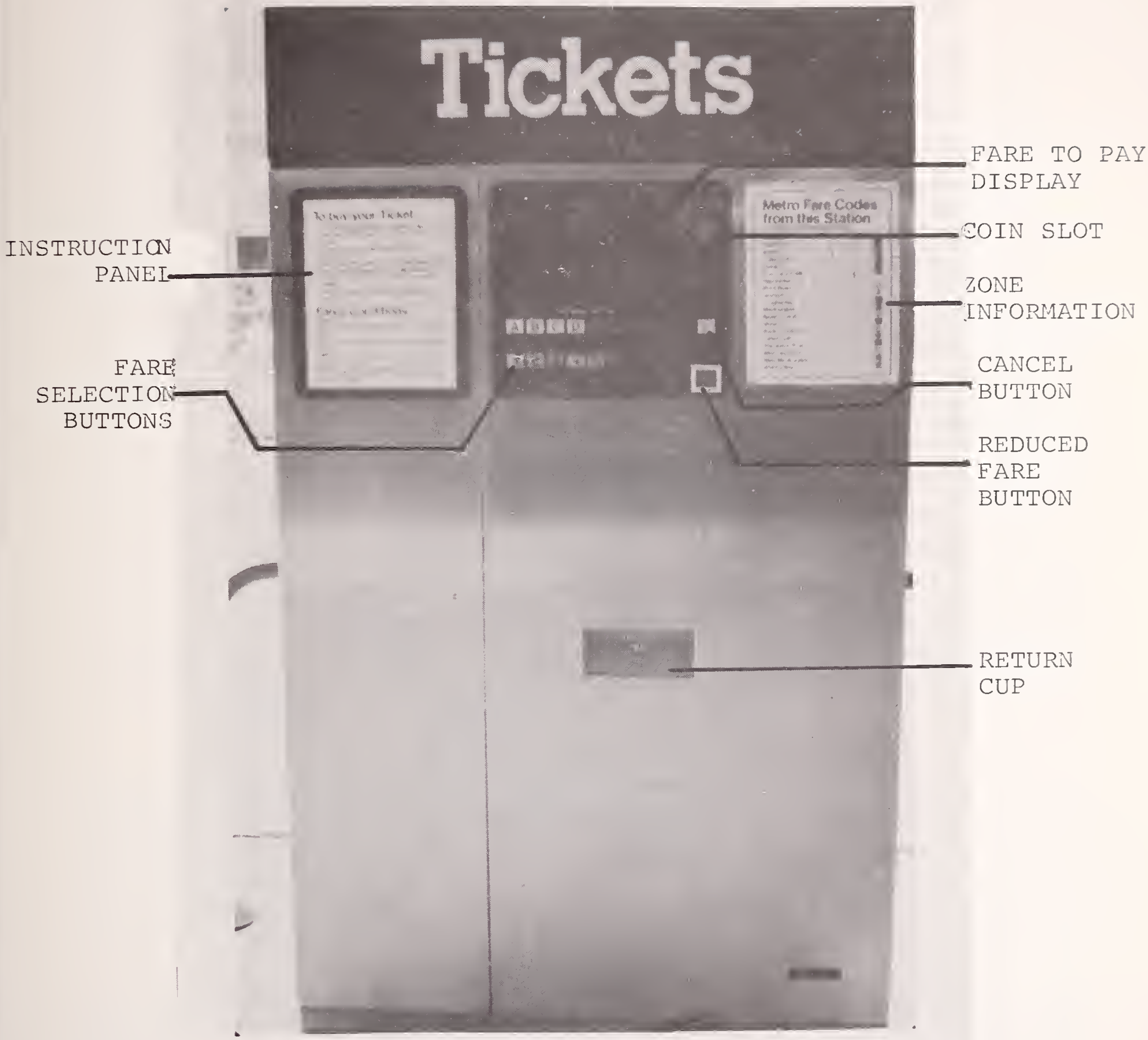

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FIGURE 2-2. TYNE AND WEAR VENDOR

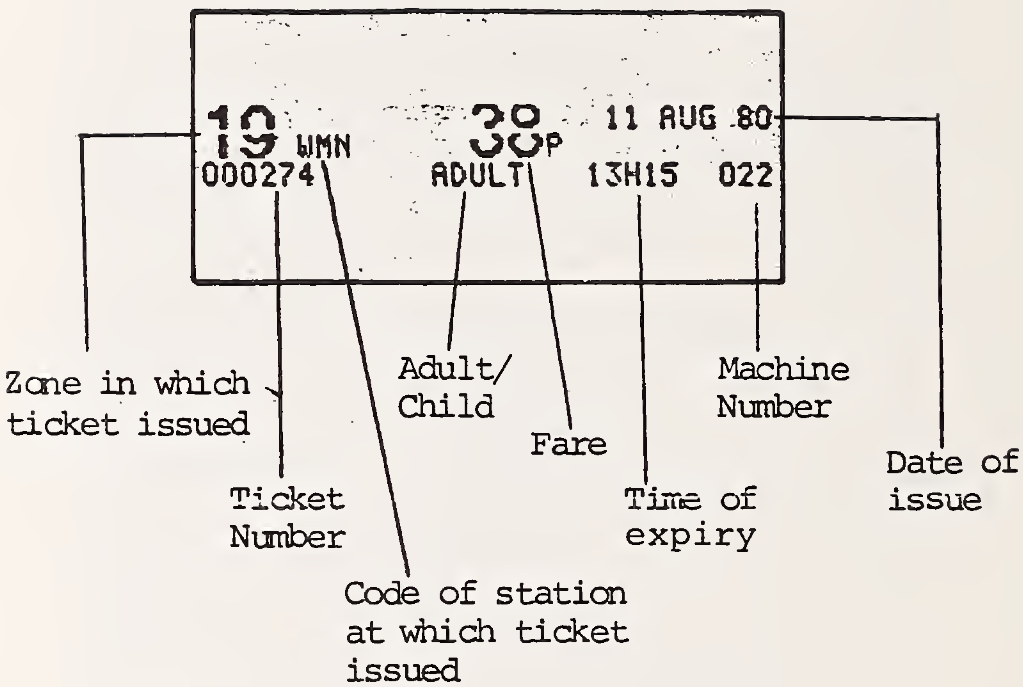

FIGURE 2-3. TYNE AND WEAR ADULT TICKET

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2.2.1.1 Patron Operation - The vendor in its normal operating mode displays the message: "I Sell Tickets and Give Change." If the machine is out of change, the message "I Have No Change. I Accept Overpayment of 19P" is displayed. Instructions are clearly displayed on each vendor with a list of stations in the system and their corresponding zones. To begin the transaction, the patron pushes the appropriate zone button. There is also a reduced fare button for eligible purchasers. If the latter is pushed, the message "Are you Entitled to Reduced Fare Travel?" is displayed flashing as a reminder. The required fare is shown in a light emitting diode (LED) display in the top right hand corner of the machine. The patron inserts coins through a single acceptance slot. After each coin is inserted, the LED fare display is reduced by the appropriate amount. If the patron desires to cancel or reselect, a cancel button can be used until sufficient money has been inserted. When enough money has been inserted, the ticket is delivered with any change through a return cup in the center of the machine. The machine is then ready for the next transaction.

2.2.1.2 Vendor Subsystems - The major subsystems and components of the microprocessor-controlled vendors are the coin selector, coin recycling subsystem, magnetic ticket issuer/reader, needlepoint printer, logic and power supply.

The general operation of all of these subsystems is presented below. Appendix A contains details of the design and functional operation of subsystems for which information was available.

<u>Coin Selector</u>

In its ready state, the selector slot is closed until the patron pushes a fare select button. This discourages vandalism

and ensures that patrons select ticket type before inserting coins. The coin selector checks the volume and material of inserted coins, rejects invalid coins, and directs valid coins to the coin recycling subsystem upon completion of the transaction. The selector can accept up to eight coins but is currently configured to accept five. These are the one, two, five, ten and fifty pence coins.

Coin Recycling Subsystem

The recycling subsystem is controlled by the microprocessor and is directly connected to the coin selector. The recycler has the capability to process up to eight types of coins, six of which can be stored in cylindrical cassettes for use as change. Depending on coin thickness, the cassettes hold a maximum of either 50 or 99 coins.

Three slots are located in each cassette: an input slot for entry of the coin from the selector, an output slot for change giving, and an output slot for dropping excess coins into the cash box.

Magnetic Ticket Issuer/Reader

This subsystem prints the ticket and drops it into the return cup for delivery to the purchaser. The subsystem consists of four sub-assemblies:

- Paper Unroller
- Ticket Feeder/Cutter
- Needlepoint Printer
- Magnetic Reader/Encoder

Once the full fare has been inserted, the feeder/cutter pulls the paper forward from the unroller, cuts the ticket to the proper length, and moves the ticket along a horizontal

drive belt to the printer. The needlepoint printer prints the relevant data clearly on the ticket, which is carried by the belt in a back and forth motion under the printer. Once printed, the ticket is moved to the reader/encoder. A write head encodes the necessary data on a magnetic strip in the center of the ticket. The encoded information is then reread, i.e., verified, by a read head. If valid, the ticket is dropped into the return cup. If not valid, the ticket is dropped into an internal waste bucket and the subsystem prints another ticket. If after a third attempt, the ticket is still not valid, the vendor automatically goes out of service and returns the money to the patron.

Logic Subsystem

The logic subsystem consists of three printed ciruit boards stored in a rack, a digital keyboard and a failure code display unit. The printed circuit boards contain the microprocessor and control electronics for the machine. The front of the rack contains push buttons for various accounting control functions and an LED display for failure diagnostics.

Power Supply

The main power of the vendor is provided by a Simplex power supply rated at 240V-50Hz. Backup power is provided by batteries in case of power failure. The backup power is designed so that a transaction in progress can be completed in the event of failure of the main power supply.

2.2.2 Automatic Gates

The automatic gates at Tyne and Wear are used for entrance control. The gate cabinets and turnstiles were built by Cubic Tiltman-Langley while the microprocessor-controlled ticket

transports were manufactured by Crouzet. Tyne and Wear interfaced the equipment from the two suppliers. There are two types of gates. The standard gate has one ticket transport and a four-section paddle barrier that rotates clockwise. The fully accessible gate has two ticket transports (one on each end) and a single "gate type" barrier that opens like a hinged door. No audit registers for accounting data are provided in the gates. Figure 2-4 shows the two types of gates.

2.2.2.1 Patron Operation - When a gate is in its operational mode, a green arrow is lighted on the front side of the gate indicating to the passenger that the gate is available. A passenger can insert the encoded ticket in any of four possible orientations. If valid and a single-ride ticket or a Transfare ticket, it is cancelled and returned through a slot in the middle of the gate top. If it is a Travelticket, it is returned but not cancelled. Simultaneously, a passenger display on top of the gate is lighted, reminding the patron to take the ticket back. The barrier is unlocked when the patron removes the ticket from the exit slot. If the ticket is not valid, a message is lighted indicating "Invalid Ticket". The ticket is returned and the barrier remains locked.

2.2.2.2. Gate Subsystems - Major subsystems of the Tyne and Wear automatic gate are a revolving four-section paddle barrier, magnetic ticket reader, canceller, logic, passenger displays, power supply and heater.

Technical details on the gates were limited and are presented in Appendix A. The following is a general description of the magnetic ticket reader controlled by an Intel 8080 microprocessor.

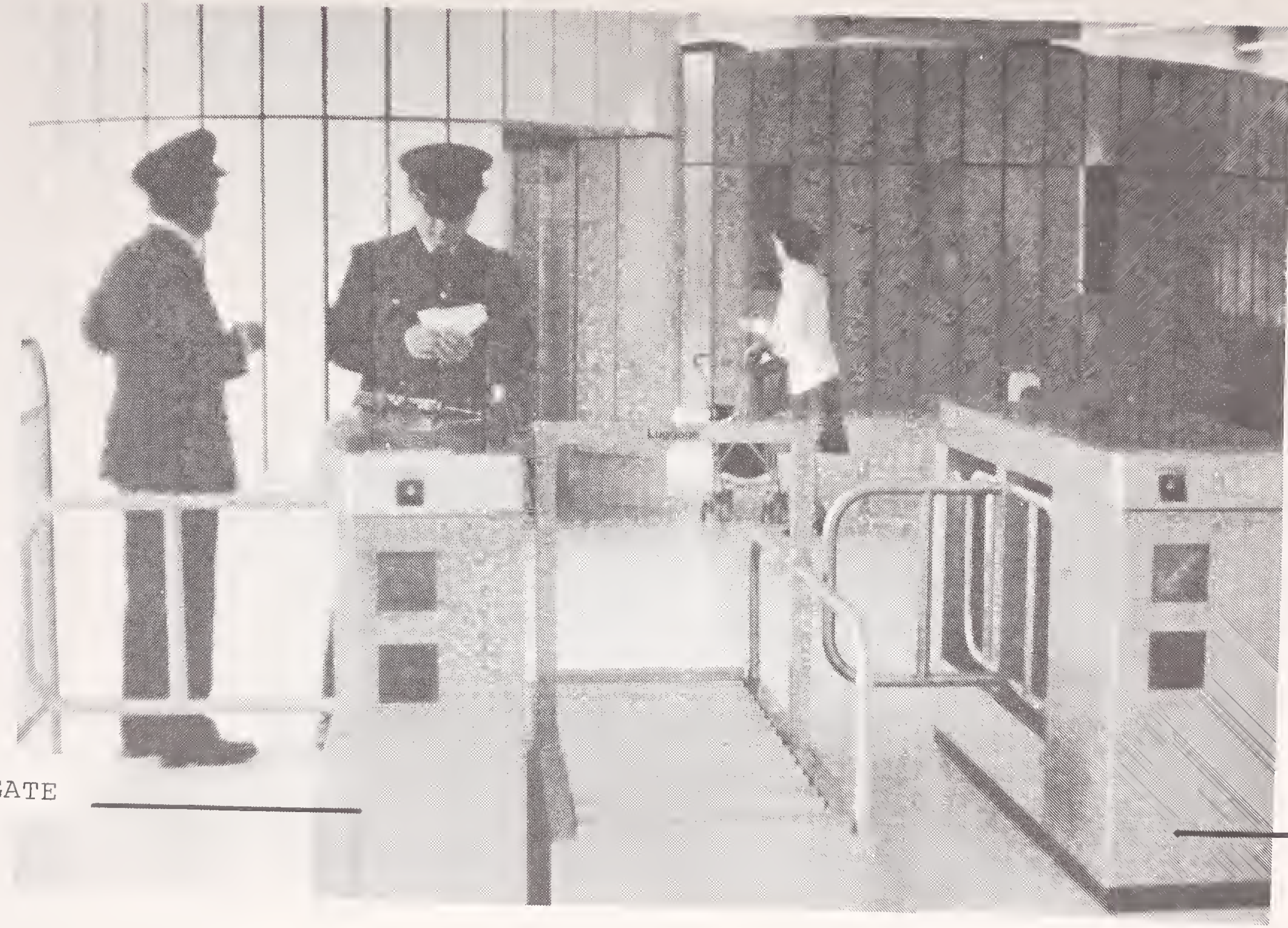

FIGURE 2-4. TYNE AND WEAR AUTOMATIC GATES

Magnetic Ticket Reader

The magnetic ticket reader is microprocessor-controlled and consists of two sets of two magnetic heads (for reading and writing), a belt-driven transport, and associated electrical and mechanical components. Upon insertion of the ticket, a sensor activates the motor which drives the belt carrying the ticket over the read heads. If the information is valid, the ticket is either erased by the write head and stamped by the canceller (if a single-trip ticket), or left alone and fed out the exit slot to the passenger (if a Travelticket). While this is happening, the logic activates the appropriate passenger information display sign and unlocks the barrier mechanism.

3. REGIE AUTONOME DES TRANSPORTS PARISIENS (RATP)

3.1 TRANSIT SYSTEM

The RATP serves Paris and its suburbs with an extensive and integrated bus and rail system. RATP operates a bus network and two coordinated rapid rail networks: the Metro subway and RER (Regional Rapid Transit) commuter lines. RATP serves a metropolitan area of about 540 square miles with a population of about 8 million. During each workday, the RATP carries about 7.5 million passengers; 4.8 million on the rail systems and 2.7 million on the bus system. RATP employs about 36,000 persons; the 1981 budget was FF 8.72 billion (about $1.6 billion). Almost 40 percent of the budget is covered by passenger fares.

The Metro, which serves Paris and its near suburbs, comprises 13 mainlines and two short feeder lines. The first Metro line began service in 1900. The system has 358 stations including 54 interchange stations. Stations are spaced an average of about 540 meters apart. The Metro carries more than four million passengers every workday (1.1 billion in 1980).

The Metro system covers 188.9 kilometers (118 miles) over narrow-gauge two-track lines. Rolling stock comprises 3500 cars of which 2,000 are motor cars and 1,500 are trailers. Ninety percent of the fleet consists of modern vehicles. A renewal policy begun 20 years ago is scheduled for completion at the end of 1981.

The RER is a wide-gauge regional express transit system consisting of two RATP lines and one French National Railway (SNCF) line serving Paris and its middle and outer suburbs. The lines for which RATP has responsibility, lines A and B, have 63 stations and cover 100 kilometers (62 miles) including

over 83 kilometers (52 miles) in the suburbs. Stations are an average of two kilometers apart. The RER runs above ground in the suburban areas, crosses Paris underground and has several exchange points with the important Metro stations. Ridership in 1980 was approximately 800,000 per working day. Rolling stock comprises 506 cars including 386 motor cars and 120 trailers. RATP embarked on a program to update the rolling stock in 1969 when Line A opened. Consequently, about 70 percent of the fleet (354 cars) is less than ten years old. Figure 3-1 presents the map of the RATP Metro and RER lines.

RATP employs a flat fare structure on the Metro and a zone fare on the RER. A ride in the urban zone costs FF3.5 or about 65 cents. The fare media on the rail systems are magnetically encoded cardboard tickets and plastic passes. Tickets are available for first and second class with first class tickets costing about 50 percent more. Roving inspectors are employed to spot check for misuse of the zone and second class tickets.

Entrance to both the Metro and RER is controlled by automatic gates that have magnetic readers. Gates are also used on the RER for exit control. Exit from the Metro does not require insertion of a ticket into a gate but patrons are encouraged to retain tickets in case of inspection.

Single one-ride tickets, groups of five or ten one-ride tickets (called carnets) and single weekly tickets are available from ticket agents and self-service ticket vendors. In addition, the agent-operated ticket issuing machine dispenses tourist, weekly, employee, and special tickets. RATP also offers patrons monthly, quarterly, and annual passes. The most common ticket used is the monthly pass known as the Orange Card (Carte Orange). The pass is issued with a photograph of the bearer for identification purposes and for entrance on buses. The card is valid throughout the entire RATP system within the zones specified. Carte Orange is used by about

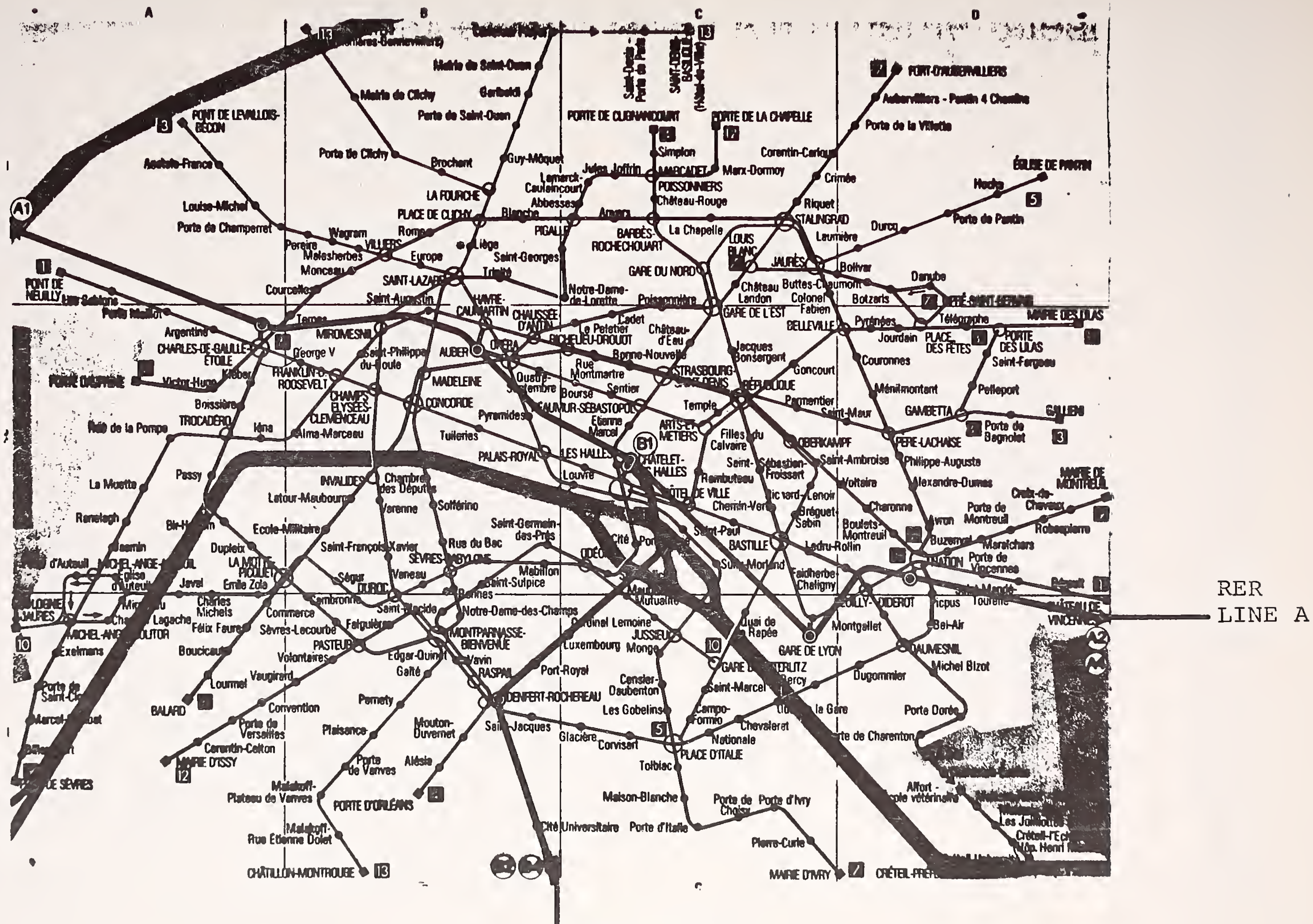

FIGURE 3-1. RATP METRO AND RER LINES

60 percent of the rapid rail passengers and 90 percent of the bus passengers during peak hours.

3.2 AFC SYSTEM

The RATP rapid rail AFC system is actually two systems - one each for the Metro and RER. Each system is controlled by a central computer. The Metro system consists of agent-operated ticket issuing machines, known as ADARs, and entry gates. The RER has self-service ticket vendors, agent-operated ticket vendors and entry and exit gates. Under a program initiated in 1977, 20 experimental self-service vendors are being tested at selected stations on both systems. Beginning in 1984, RATP plans to replace the self-service vendors now in-service.

The Metro began using magnetically encoded tickets in 1973, when the first of the ADARs were put into service. Currently the Metro AFC system comprises 360 ADARS and about 1,700 automatic gates. All are connected directly (hard-wired) to a central computer. The AFC system was designed and manufactured by Compagnie Generale D'Automation (CGA) and the Societe D'Etudes et de Systemes D'Automation (SESA) with the collaboration of the Societe de Construction D'Appareils Mecaniques De Precision (CAMP) and Marcel Dassault. The system was designed to carry out the following functions:

- Distribution of tickets;
- Control of receipts;
- Entry control;
- Passenger traffic statistics;
- Maintenance assistance.

The RER AFC system was implemented when Line A began operation in 1969. The current system consists of about

540 automatic gates, 370 self-service vendors, and 50 agent-operated vendors, similar to the self-service machines. Of the 540 gates, about 170 are entry-only, 310 exit-only, and about 60 are reversible. Each piece of equipment is connected to one or more computers located in each station. The station computers are in turn connected to a data concentration system, i.e., the central computer. The RER AFC system was designed and manufactured by Crouzet with the collaboration of CGA and CAMP. The system provides for ticket distribution, entry and exit control, control of receipts and traffic statistics. Beginning in 1980, RATP has been installing microprocessor-controlled Crouzet gates. There are currently about 270 in-service and about 120 on order.

3.2.1 Metro AFC Equipment*

3.2.1.1 ADAR - The ADAR is an agent-operated ticket distributor that produces all cardboard tickets and several plastic passes. Passes and tickets are Edmondson size, the same as those sold by Tyne and Wear vendors. In order to prepare a ticket, the agent punches one or two buttons on a selection keyboard for destination and ticket category. The information is transmitted to the central computer, which returns a message to the unit with information to be encoded. Prior to delivery of the ticket, the ADAR verifies the encoded message. The ADAR also prints necessary data clearly on the ticket. The printed data includes date and time and station of issue. Figure 3-2 presents the ADAR.

In addition to the issuing of tickets, the ADAR provides the following functions:

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*Equipment manuals detailing equipment design and subsystem operation were not available from the property.

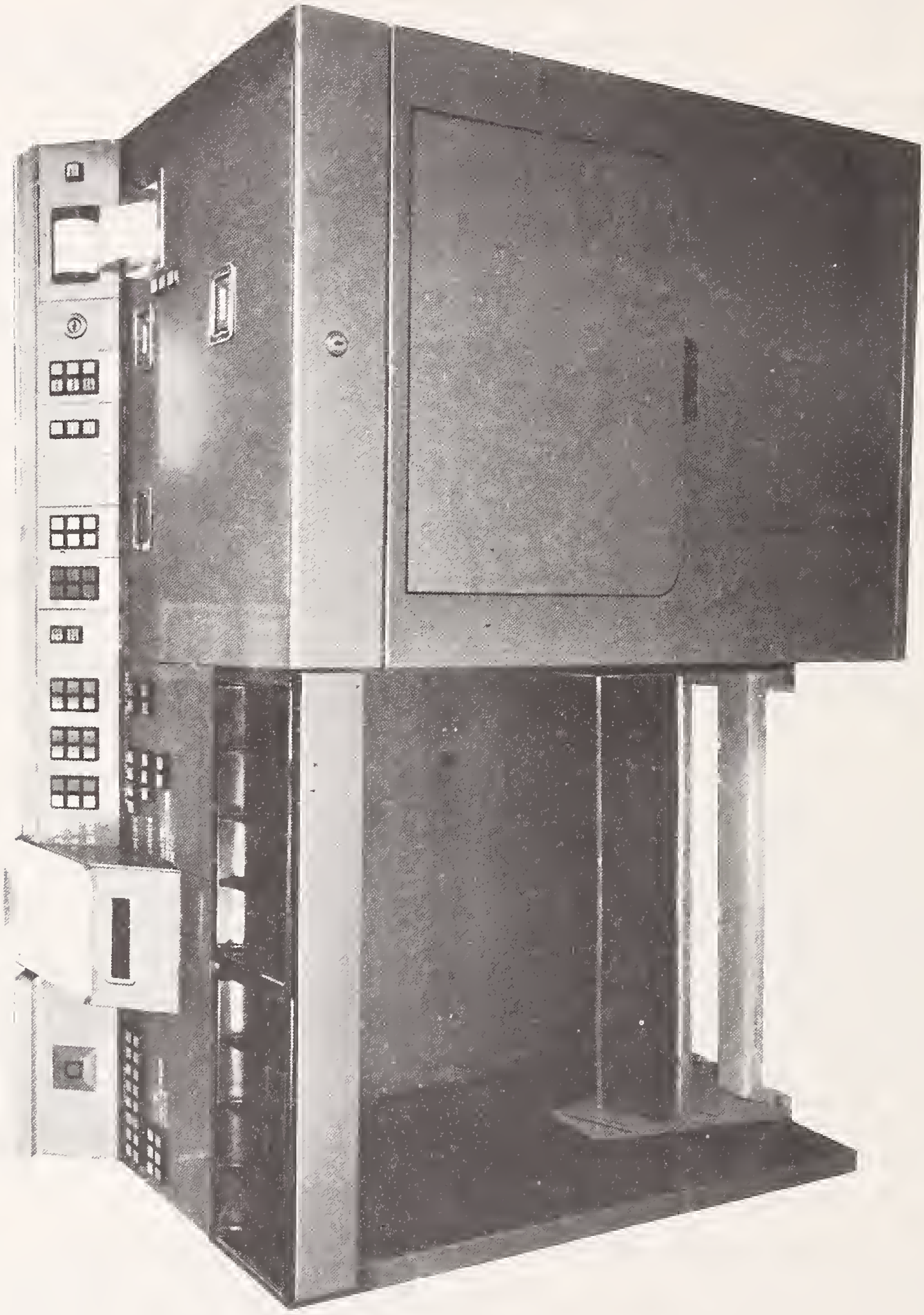

FIGURE 3-2. RATP METRO ADAR MACHINE

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- Teleprinting i.e., displaying messages sent from the computer;

- Ticket reading i.e., checking dubious tickets for validity;

- Time keeping of personnel by reading a magnetic badge;

- Station control and alarms.

In order to accomplish the last function, an ADAR has associated with it the control and alarm buttons for all the AFC equipment in the mezzanine. These controls are built into the agent's desk in the ticket booth. The controls are:

- A start up switch for the gates and the ADAR;

- A switch that controls the different uses of the gates (e.g., freewheeling and local mode);

- Control light signals for the ADAR and gates;

- A sound alarm that is triggered when the ADAR is nearly out of paper or goes out of service, or when the gates have jams in the transport;

- A jam clearing feature that is designed to clear the gates of ticket jams.

3.2.1.2 Metro Automatic Gates - The 1,700 automatic gates in service on the Metro provide for entrance control to the rail system. Each gate is connected to the station ADAR and to the central computer. The gates are of two generations, 1969 and 1973. Both models were produced by a collaboration of companies, the principals of which were CAMP (mechanical) and

CGA (electronics). There are about 700 of the 1969 model gates and 1,000 of the 1973 model. Each gate incorporates a ticket transport and one of the following barrier mechanisms used on the Metro: tripod, quadripod or high-standing retractable. The gates are designed so that they can operate properly in the event of the computer failure.

The gates can process a ticket in less than one second with a maximum flow rate of about 30 patrons per minute. The gates incorporate both a printer and a canceller and have the capability of capturing tickets if so ordered by the central computer. The data printed on the ticket are time, part of day, day of the week, number of the week within the year, and number of the gate. Figure 3-3 presents the tripod and quadripod gates.

Patron Operation

Patron operation is similar to that for the Tyne and Wear gate. In its normal operational mode, a green arrow is lighted on the front side indicating that the gate is available for use. The patron can insert the encoded ticket in any of four possible orientations. If the ticket is a valid single-ride ticket, it is cancelled and returned through the exit slot. Simultaneously, the barrier is unlocked and a passenger display just above the exit slot is lighted to remind the patron to take the ticket back. If the ticket is a weekly ticket or a pass, it is not cancelled. If the ticket or pass is not valid, it is returned, an "Invalid Ticket" message is displayed, and the barrier remains locked.

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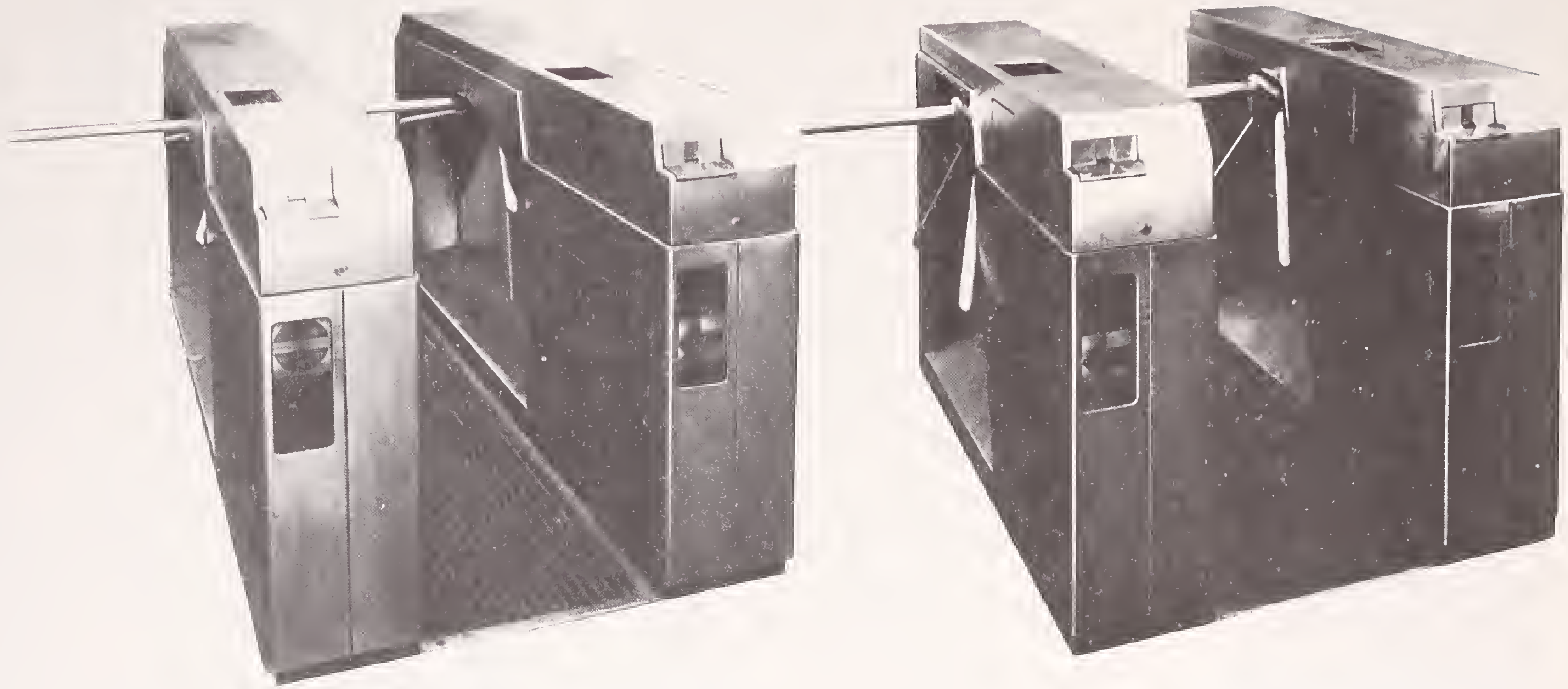

Quadripod Turnstile

Tripod Turnstile

FIGURE 3-3. RATP METRO TRIPOD AND QUADRIPOD GATES

Gate Subsystems

Major subsystems of the Metro gates are a barrier, magnetic ticket reader, needlepoint printer, canceller, logic, passenger display, power supply and heater. Three types of barriers are used: tripod, quadripod or high standing hydraulic. Information available from RATP on specific subsystems was limited to general information on the barrier and magnetic ticket reader subsystems.

Barrier

The barriers used on the Metro gates include tripod and quadripod rotating assemblies that lock after one revolution and prevent backward motion. Also used by RATP are high-standing hydraulic barriers that retract upon insertion of a valid ticket. In case of power failure, the tripod barrier freewheels, the quadripod folds in, and the highstanding barrier remains in the retracted position.

Magnetic Ticket Reader

The magnetic ticket reader in the 1974 model gate consists of a belt-driven transport with three sets of two magnetic heads - read, write, and reread, i.e., verify. When a ticket is inserted, a sensor activates a motor that powers the transport. The encoding on the ticket is read and information is sent to the central computer for a validity check. The computer returns with a command to proceed or to reject and return the ticket as invalid. If the ticket is valid, data sent by the computer are encoded on the ticket. The new message is reread and sent to the computer for a verification check. If the new read message matches the encoded message, the computer sends a signal to unlock the barrier.

3.2.2 RER AFC Equipment

3.2.2.1 RER Vendors - The RER began operation in 1969. At that time, Crouzet vendors were installed for both self-service and ticket agent operation. The vendors are connected to station computers which in turn are connected to a central computer. The vendors provide transaction and accounting data to the computer, but they do not provide failure data to the computer.

The 370 self-service vendors are divided into three groups with respect to the types of tickets vended. One group is programmed to sell individual and carnets of urban zone tickets in first or second class. Another sells the same types of tickets for all zones. A third sells weekly second-class tickets for the urban zone only. The all-zone vendor is shown in Figure 3-4.

The vendors incorporate six coin acceptors with a recylcing change system consisting of stack storage units located directly beneath each acceptor. The vendors accept the following coins in a separate slot for each - 5FF (French Franc), 2FF, 1FF, 1/2FF, 20 centimes and 10 centimes. Between 1970 and 1980, these machines had 10FF bill acceptors that were discontinued because of fraud and unreliability. The acceptors would not accept old bills and often would keep bills but not vend tickets.

Patron Operation

In its normal operating mode, the vendor displays an "In Service" message in the upper right hand corner. If out of service, the vendor indicates the message in the same place. Instructions and a list of stations and their corresponding

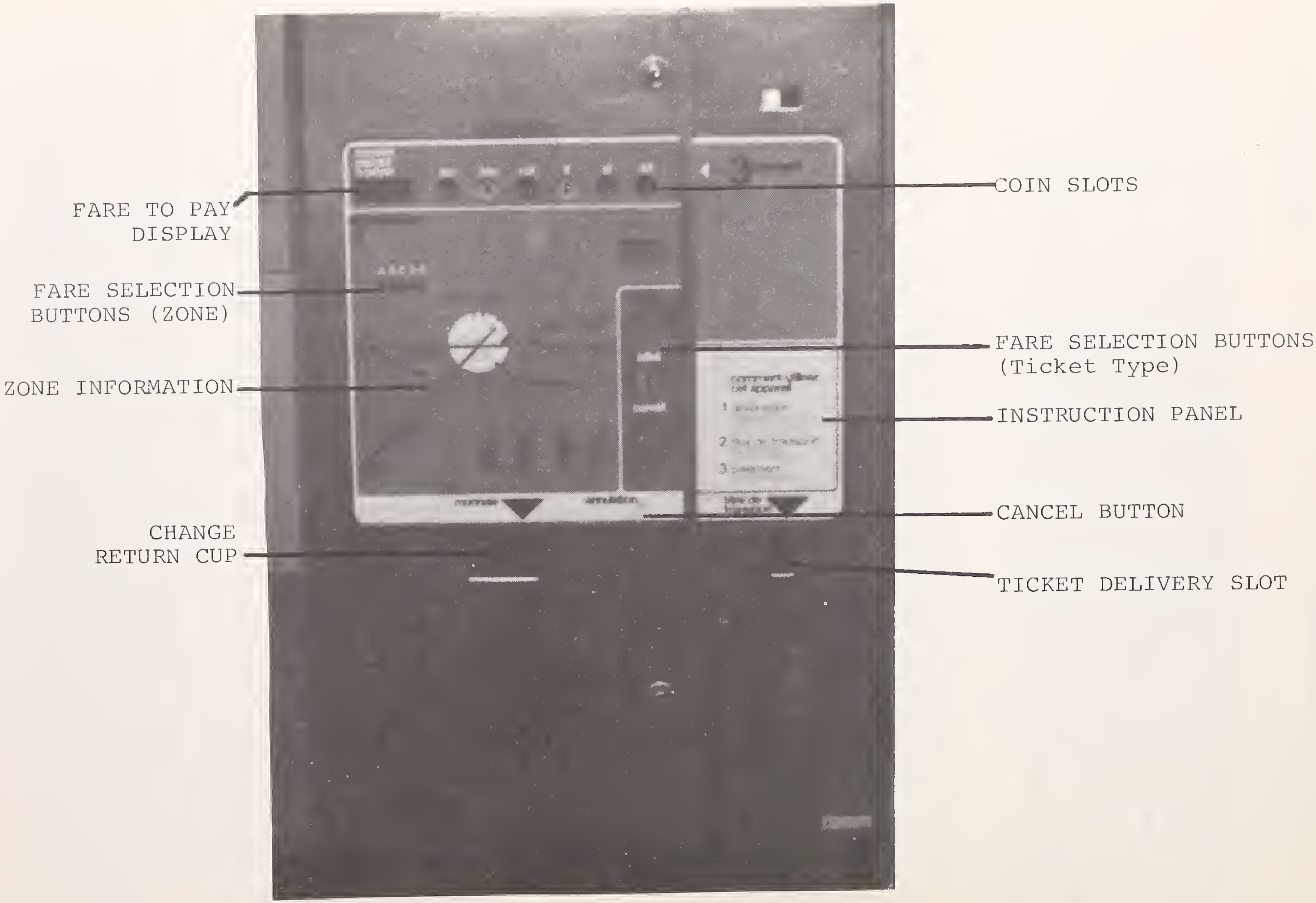

FIGURE 3-4. RATP RER ALL-ZONE VENDOR

zones are clearly displayed on each vendor. The instructions are presented as three steps: (1) zone selection, (2) ticket selection, and (3) payment.

The patron determines the zone of destination, pushes a zone button, then selects the type of ticket by pushing a second button. The fare is indicated on an LED display in the upper left side. The patron inserts each coin through its assigned slot. After each coin is inserted, the fare display is reduced by the appropriate amount. If the patron desires to cancel or reselect, a cancel button can be used until sufficient money has been inserted. If reselection is desired before insertion of the first coin, it can be done by pushing a new zone or ticket selection button. When enough money has been inserted, the ticket or carnet is delivered through a slot in the lower right hand side of the machine. Any change required is delivered through a return cup in the center of the machine.

Vendor Subsystems

It is important to note that these machines are old technology incorporating first generation design in many areas such as the coin acceptor, recycling system and electronic logic. The subsystems are coin acceptors, coin recycling, magnetic ticket issuer/reader, printer, logic, power supply and leafer. There are six coin acceptors and the recycling subsystem uses stack storage to hold coins. Documents on specific subsystems were not available from the property.

3.2.2.2 RER Automatic Gates - The RER has about 540 automatic gates in its AFC system. Each gate is connected to an agent control desk and to a station computer. About half the gates are the 1973 model-year CAMP/CGA gates; the other half are

microprocessor-controlled gates incorporating Crouzet transporters and Klein barrier subsystems. The barriers used on the RER are tripod or normally open hydraulic paddle barriers which close if an inserted ticket is deemed invalid. The agent control desk provides for start-up and mode setting of the gates as well as for clearing of jams. The latter facility is basically the same as that associated with the ADAR machine.

There are about 170 entry-only, 310 exit-only and 60 reversible gates in service. The difference between the entry and exit gates are the absence of a printer and the addition of a take-in device for ticket capture in the exit gates. Patron operation for both types is basically the same as that described for the Metro gates.

RER Gate Subsystems

The CAMP/CGA gates have been described in Section 3.2.1.2. The only difference between the Metro gates and the RER CAMP/CGA entry gates is the normally open hydraulic barrier mechanism.

The Crouzet gates are microprocessor-controlled and incorporate a Klein tripod barrier. They are similar to, but slightly more sophisticated than, the Tyne and Wear gates, also manufactured by Crouzet. (The major difference is that the RER gates communicate with a station computer during each transaction.) The major subsystems of the RATP Crouzet gates are tripod barrier, magnetic ticket reader, needlepoint printer, canceller, logic, test diagnostics, passenger display, power supply, and heater.

3.2.2.3 RATP Experimental Vendors - As part of a program to replace the Crouzet vendors currently in-service, RATP has been

experimenting with vendors from Crouzet and Marcel Dassault. The ten Crouzet machines have been in service since 1979, the ten Dassault machines since 1980. Similar to the use of the older Crouzet machines, some new vendors are set up to sell urban zone tickets only, others sell tickets for all zones. RATP intends to soon experiment with a third vendor, manufactured by CGA. The replacement program is scheduled to begin in 1984.

Figure 3-5 presents one of the new Crouzet vendors. The Crouzet machine is microprocessor-controlled and technically the same as the Tyne and Wear vendor described in Section 2.2.1.2. The only differences are that the RATP machine incorporates a stacking device for delivery of carnets of tickets, uses only one cash box, and has different display panels.

The ten Dassault vendors also utilize microprocessor technology. The vendor, shown in Figure 3-6, incorporates an Autelca coin selector and coin recycling subsystem. The machine has an enlarged passenger information LED display for communication with patrons. It is programmed to display information in English and German as well as in French. A description of the Autelca coin recycling subsystem is contained in Appendix D.

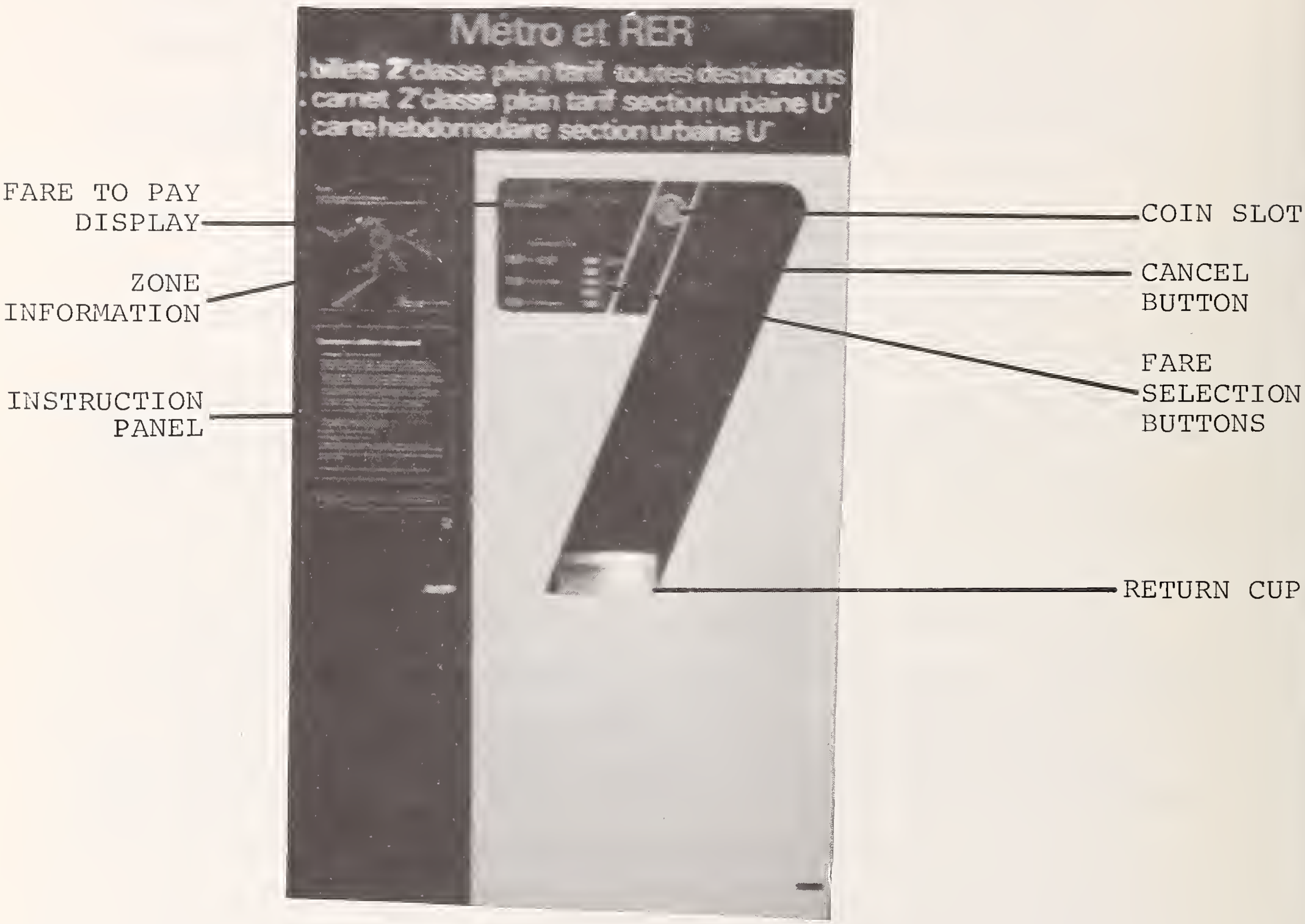

FIGURE 3-5. RATP CROUZET EXPERIMENTAL VENDOR

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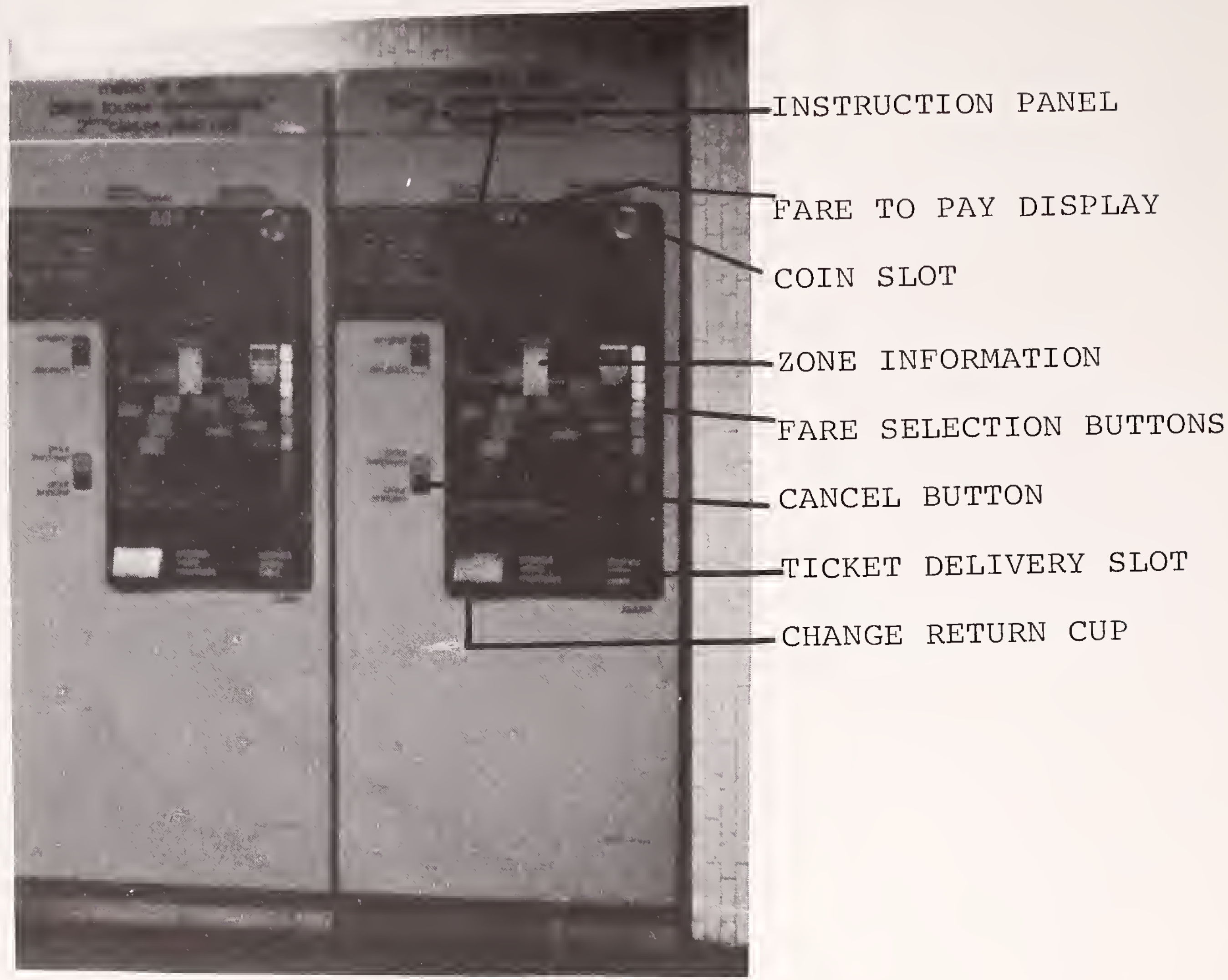

FIGURE 3-6. RATP DASSAULT EXPERIMENTAL VENDORS

4. STUTTGARTER STRASSENBAHNEN (SSB)

4.1 TRANSIT SYSTEM

Stuttgarter Strassenbahnen operates a trolley and bus system serving Stuttgart, West Germany, and its surrounding communities. The population served by SSB is approximately two million and the area covered is approximately 50 kilometers in diameter. The SSB system comprises 10 trolley lines with 400 trolleys and 60 bus lines with 300 buses. The surface line length is 500 kilometers and the subway line length is 9 kilometers. The SSB is integrated with a heavy rapid rail commuter transit system known as the S-Bahn. SSB also has connection points with the German National Railway System.

Ridership on the SSB is approximately 400,000 per workday. In 1979, ridership was 154 million. SSB employs 3,000 people and covers seventy percent of its operating cost through the farebox.

A zone fare system is used, with passengers purchasing tickets from self-service vendors or bus drivers, or purchasing passes from SSB outlets located in banks and stores. Fares range from 1.70DM to 6.60DM (about \$.70 - \$2.80).

An honor system is used whereby the passenger is responsible for his own ticketing, and access to and from the system is not controlled. Forty plain-clothes inspectors make random checks of passengers during peak periods. The penalty is 40DM, payable immediately. The fraud rate has been estimated by SSB at 1.5 percent.

Several types of tickets and passes are available in the SSB system. These are single-ride, multiple-ride, i.e. five-ride, and 24-hour tickets, and weekly and monthly passes.

Approximately 67 percent of the riders use weekly or monthly passes. The single ticket is valid for one trip with any number of changes as long as the passenger keeps travelling toward the destination. The single-ride, multiple-ride and 24-hour ticket are available from self-service vendors located throughout the SSB system.

4.2 AFC SYSTEM

The SSB AFC system utilizes microprocessor-controlled Autelca vendors that sell single and five-ride tickets. The tickets are not magnetically encoded. In addition to the vendors, cancellers are located on SSB vehicles for use with the five-ride tickets. There are approximately 490 vendors in the SSB system. The machines are located at every trolley stop and at large bus stops. The vendor accepts coins only, sells adult and child (reduced-fare) tickets and provides change using a coin recycling subsystem. Figure 4-1 presents the SSB vendor and Figure 4-2 shows the two types of tickets sold. Note that Appendix D presents a list of the data elements printed on the tickets.

4.2.1 Vendors

4.2.1.1 Patron Operation - The vendor displays information that provides patrons with instructions for operation and that helps patrons determine the zone of their destination. Once the zone has been determined, the patron selects the ticket by pushing the appropriate button on a lighted fare selection panel. A "fare to pay" LED display informs the purchaser of how much money is required for ticket purchase. After the selection button has been pressed, the single slot of the coin acceptor opens to receive the coins. The patron inserts each coin through the slot which closes briefly to process each

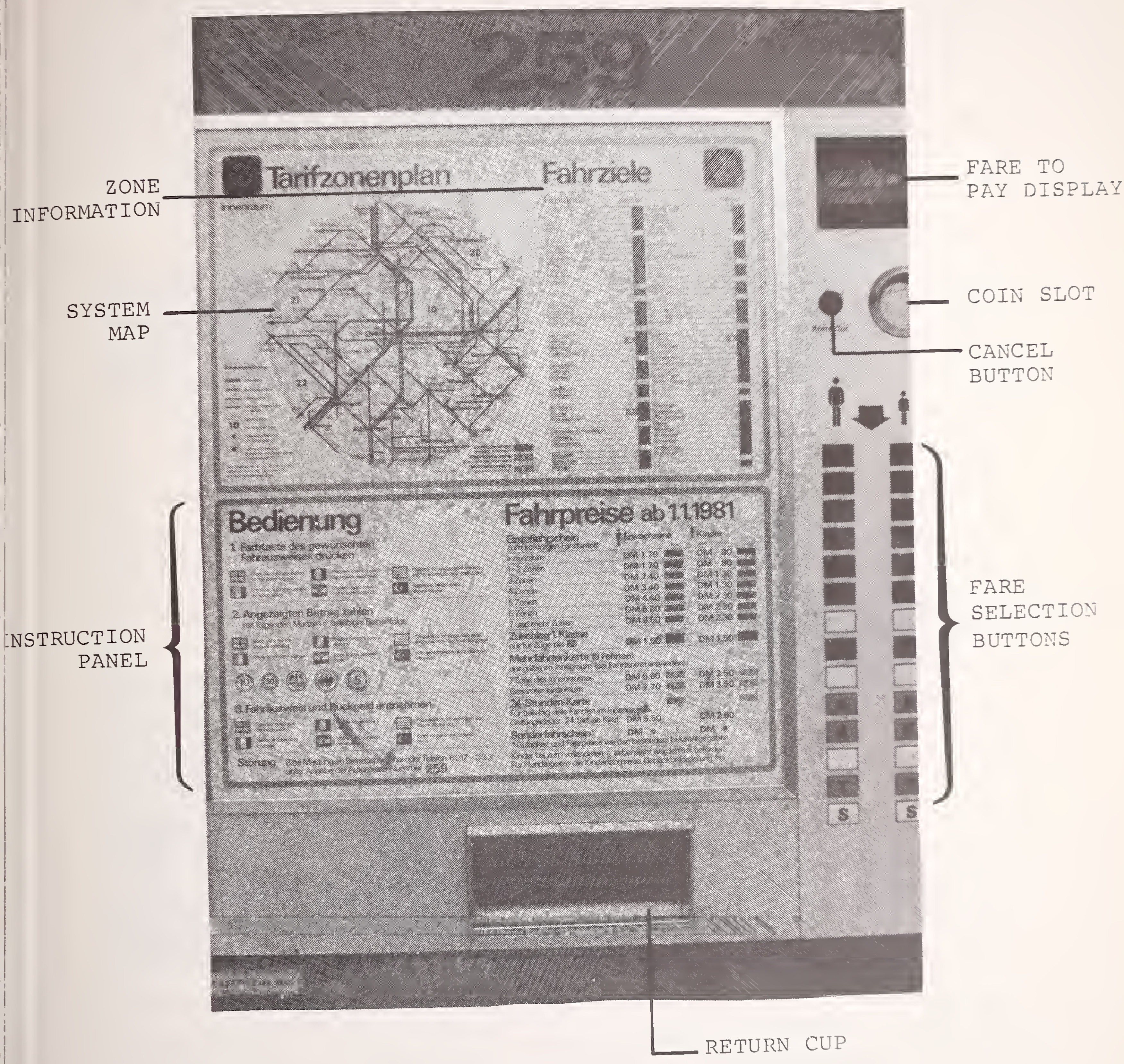

FIGURE 4-1. SSB VENDOR

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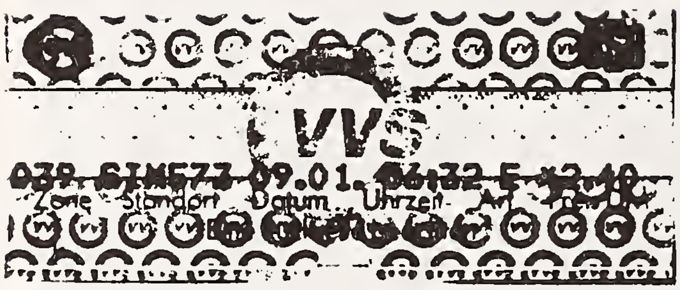
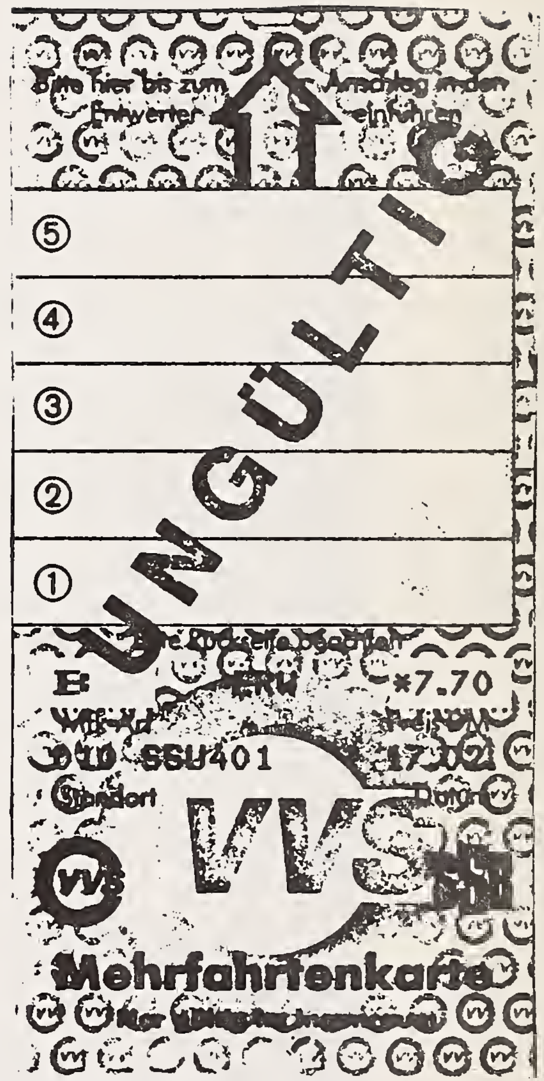


SINGLE-RIDE TICKET



MULTIPLE-(5-RIDE) TICKET

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FIGURE 4-2. SSB VENDOR TICKETS

coin. Until the first coin is inserted, it is possible to reselect by pushing another fare button. Once the first coin is inserted, reselecting is possible only by pushing the cancel button. As each coin is inserted, the fare to pay is updated and displayed. Once the required fare has been reached, the ticket is delivered with any change via a return cup located in the center of the machine.

4.2.1.2 Vendor Subsystems - The major subsystems and components of the SSB vendors are coin selector, coin recycling subsystem, ticket transport, needlepoint printer, logic subsystem and power supply.

A difference in design between the SSB vendor and the Tyne and Wear vendor is that the SSB ticket transport is a sprocket feeder that moves the paper vertically into the printing subsystem. The ticket is then printed, cut and dropped into the return cup. This difference is in part due to the fact that the SSB vendor does not magnetically encode tickets. Appendix D provides the details of the major subsystems of the machine. The general description of the coin selector, coin recycling subsystem, and needlepoint printer is presented below.

<u>Coin Selector</u>

Inserted coins are checked for size and material against model coins inside the selector. If valid, the coin is held in escrow and dropped into the coin recycling subsystem upon transaction completion. If invalid, the coin is returned to the purchaser. The selector will accept five types of coins - 5DM (Deutsch Mark), 2DM, 1DM, 50 pfennig and 10 pfennig. It has the capability to accept a sixth coin. Consideration is being given in Germany for minting of a 10DM coin.

Coin Recycling Subsystem

The coin recycling subsystem in the SSB vendors consists of circular storage units or discs. The subsystem can process up to six types of coins. Valid coins are directed by the selector to the appropriate disc. Coins are fed from the discs to either the return cup as change or to a cash box when the disc has reached its capacity. In some vendors the recycling subsystem is augmented with an extra store of 10 pfennig coins. This storage unit is non-recycling, but feeds the 10 pfennig recycling disc. It is necessary because these coins are the most widely used for change.

Needlepoint Printer

This unit is a mosaic needlepoint printer that has a printing head containing seven needlepoints. The unit prints at a speed of 200 characters per second and is reprogrammable via the logic subsystem. It has the capability for security purposes to print safety marks in the form of negative imprints.

The paper is fed vertically to the printing unit which is located in the top of the machine. Once printed, the ticket is cut by a self-sharpening knife and dropped into the return cup.

5. PERFORMANCE DATA

In order to assess the performance of the AFC equipment at each property, on-site performance data were collected by the IOCS project team in accordance with procedures described in the Property Evaluation Plan. In addition, research was undertaken and interviews with property personnel were held to obtain equipment manuals and performance data maintained by the properties. Tyne and Wear and SSB maintained both transaction and failure data in a combined form useful for analysis purposes. RATP, on the other hand, maintained only comprehensive, computer-generated transaction data. Failure data from the RATP were not available.

5.1 DATA COLLECTION PLAN

A data collection plan was developed for each property. Based on the equipment in use, each plan was designed to survey a sample of the full set of AFC equipment in-service. The plans included the collection of data on the performance of the major elements of vendors and gates, such as coin acceptors and ticket transports.

The plan called for a one-week survey to be conducted in July 1981, at each property by two IOCS personnel. Under ordinary circumstances, the procedure is to survey two mezzanines (one per surveyor) during both the morning and evening rush hours (approximately 2 to 2-1/2 hours).* At Tyne and Wear, the normal procedure was followed, whereas at both RATP and SSB, for reasons described below, the plan was altered slightly to accommodate traffic conditions and/or equipment use.

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*A "mezzanine" is defined as an entrance to a station.

At each property, stations were selected with the assistance and approval of property personnel. At Tyne and Wear, it was possible to survey two stations in the morning and two in the evening. Each of the stations surveyed in the morning comprised two mezzanines. It was possible to collect data at each mezzanine because the surveyor could see both mezzanines from his vantage point. The evening stations each had only one mezzanine.

At RATP, the situation was quite different. Due to the diversity of the equipment and large traffic volumes, surveys were taken at different stations. In addition, some mezzanines, due to their size, equipment configuration, and volume of traffic, required observation by two surveyors. RATP was unable to provide personnel to open AFC equipment for on-site transaction data. Instead, it was agreed that the computer system would generate transaction data for the surveyed stations. Due to computer problems, the data were not provided, precluding a quantitative reliability assessment of the RATP equipment.

At SSB, it was decided with property personnel that a three-hour survey in the evening peak period at the central station (Hauptbahnhof) would provide sufficient data. This was done because the station had the largest concentration of vendors and the highest traffic level. (The majority of the stops on the SSB system have two vendors, one each on the outbound and inbound platform).

5.2 DEFINITIONS OF PERFORMANCE MEASURES

5.2.1 Reliability

Reliability is defined as the probability that AFC equipment or their elements, i.e., major subsystems, will

successfully accomplish their functional task. In terms of the equipment surveyed at the three European properties, successful transactions are defined as follows:

- <u>Vendors</u> - successful delivery of a ticket, or as possible in the case of RATP vendors, a carnet i.e., book of 5 or 10 tickets;

- <u>Gates</u> - successful admittance of a patron with a valid ticket or pass.

For each machine type, the success of elements can be defined in the same manner. For example:

- <u>Vendor Ticket Transport</u> - successful delivery of a ticket or carnet of tickets;

- <u>Gate Ticket Transport</u> - successful read/write/verify and return, if appropriate, of a valid ticket.

Reliability is expressed in three different ways:

1. As probability of a successful transaction:

$$R = \frac{\text{Total Transactions} - \text{Total Failures}}{\text{Total Transactions}}$$

2. As the mean number of transactions per failure:

$$MTF = \frac{1}{1-R}$$

3. As the mean time between failures:

$$MTBF = \frac{\text{Total In-Service Time}}{\text{Total Failures}}$$

The first two measures of reliability have been utilized for each property to assess the performance of the overall machine i.e., machine as a whole, and specific elements.

Elements for which performance measures were generated were the magnetic ticket issuer/reader of the Tyne and Wear Vendor and the printer subsystem of the SSB vendor. MTBF measures have been generated only for the machine as a whole.

For the computation of reliability measures, two sets of data are utilized. The first set is data that IOCS observers collect during an on-site survey at a property. For each type of machine, transaction data and failure data are collected. Each time a machine fails to successfully carry out its mission, a failure is recorded. Failures are classified in accordance with the IOCS Property Evaluation Plan. The second set of data is that maintained by the property. Transaction data on equipment are provided that indicate tickets sold or patrons admitted or allowed exit. Failure data are either in the form of permanent maintenance records for each machine or failure reports filed by technicians. Both transaction and failure data can be at the machine, mezzanine, station or system level.

Both forms of property-supplied failure data have their limitations. Failure reports or logs filed by technicians often contain incomplete information as to the nature of the problem and time to repair. In addition, the type of action taken by the technician is not always clearly indicated, making it more difficult to judge the severity of the failure. Permanent maintenance records of machines are often not kept. When they are, they often do not indicate the nature of the problem that required the maintenance action. Instead, they may indicate only that a particular part was replaced. For example, SSB records show replacement of parts for preventive maintenance and unscheduled repair. Details on the problems that led to the replacement were not always included in the record.

Another limitation of property-maintained failure and maintenance data results in reliability measures based on such data being higher than reliabilities based on data collected by on-site surveyors. This situation occurs because maintenance records and failure reports do not indicate how many times a machine failed to complete its mission before the failure was detected and corrected. It is not true that every time a failure occurs, a machine goes out of service. Some failures occur intermittently depending on the function involved. For example, a gate may allow entry to some patrons with valid tickets but not to others. This situation may be due to dirt that has accumulated among magnetic heads in the ticket transport. Eventually the problem may become severe enough that all patrons will not be allowed entry. However, for this one failure recorded by the technician in a failure report and subsequently recorded on the permanent maintenance record of the gate, the machine may have failed to complete its mission more than one time. For vendors, random logic problems can occur that prevent ticket delivery to patrons intermittently. The problem may be attended only after several patrons have complained.

All failures used in the performance assessment are classified in accordance with the IOCS Property Evaluation Plan. However, in some cases, situations may arise which are not, strictly speaking, machine failures. These "occurrences" include such diverse events as bent or foreign coins being used in vendors, crumpled or torn tickets, or worn passes being used in the gates. For the on-site data, these occurrences have been separated from failures. For the property-supplied data, failures due to bent coins were included in the failure data for SSB, but other occurrences have not been included.

The reliability tables shown throughout the report incorporate two statistical measures - significance tests and confidence intervals. For performance measures, a t-test of

proportions has been used to determine whether a machine, or group of machines exhibits a performance measure significantly different from the sample or system total at a specified confidence level. For this analysis, the t-test is applied at the 95 percent confidence level.

The confidence intervals have been generated for both sample and system MTF measures. In some cases, due to the size of the sample, only lower bound MTF rates have been generated. For this analysis, a 95 percent confidence interval has been used because this is a standard measure for operations analysis. The confidence interval provides the upper and lower bounds of the MTF measure. It indicates the interval in which there is a 95 percent probability that the "true" reliability falls.

5.2.2 Availability

Availability is defined as the probability that AFC equipment will be operating satisfactorily at any point in time. Availability is calculated by dividing the total in-service time by the total operating time and converting the result into a percentage. Total operating time is comprised of: (1) total in-service time (operating and available for service); and (2) total downtime (i.e., combined duration of all failures, including active-repair time and response and logistic time). An example of logistic time is time spent going for parts. Availability is expressed as follows:

$$A = \frac{\text{Total Operating Time - Total Downtime}}{\text{Total Operating Time}}$$

5.2.3 Maintainability

Maintainability is defined as the time required to repair failures and is usually expressed as average downtime (ADT) and

mean time to repair (MTTR). Average downtime is the more widely-used measure and indicates the average time that AFC equipment will be out of service per failure. It is calculated as follows:

$$\text{ADT} = \frac{\text{Total Downtime}}{\text{Total Failures}}$$

where total downtime equals response, active repair and logistic time.

Mean time to repair (MTTR) statistics are developed for hard failures that require action by a maintenance technician. Hard failures are defined in the Property Evaluation Plan as failures that require an active repair time greater than 20 minutes or require component replacement. Mean time to repair is based on the total downtime for all hard failures and the total number of hard failures. It is expressed as:

$$\text{MTTR} = \frac{\text{Total Downtime (Hard Failures Only)}}{\text{Total Hard Failures}}$$

5.3 TYNE AND WEAR METRO RESULTS

On-site survey data were collected on 19 vendors and 16 gates at four Tyne and Wear stations during a five-day period from 13 July - 17 July, 1981. Data were collected over approximately 10 hours for each station. Table 5-1 summarizes the survey data collected at Tyne and Wear. Due to the coin recycling subsystem, vendor coin counts were not possible to obtain. This precluded a quantitative performance assessment of the coin acceptor.

In addition to the survey data, Tyne and Wear provided the following performance data for analysis purposes:

- Vendor failure distributions for April and May 1981;
- Vendor MTF rates for the same months.

TABLE 5-1. SUMMARY OF TYNE AND WEAR DATA COLLECTION

STATION	PEAK PERIOD SURVEYED	NO. OF DAYS SURVEYED	NO. OF VENDORS	VENDOR TRANSACTIONS	NO. OF GATES	GATE TRANSACTIONS
Whitley Bay	AM	5	5	1,055	4	1,465
Monkseaton	AM	5	4	1,308	4	1,920
Haymarket	PM	5	7	10,222	5	15,210
Regent Centre	PM	5	3	1,538	3	2,002
Sample Total			19	14,123	16	20,597

The subsections that follow present the results of the on-site performance data, followed by the performance measures generated from the property-supplied data.

5.3.1 Tyne and Wear AFC Reliability

Vendors - On-Site Data

Tables 5-2 and 5-3 summarize the reliability measures for each station and each vendor respectively, based on the on-site survey. As can be seen in the tables, only three failures occurred at 19 vendors over more than 14,000 transactions resulting in an MTF rate of 4,708. The lower bound of the 95 percent confidence interval was 2,219, indicating that there is a 95 percent probability that the "true" MTF rate lies above that number. Due to the sample size, an upper bound was not computable. Table 5-4 shows that the MTBF rate was 71.7 hours.

Gates - On-Site Data

The reliability by station of the 16 gates observed during the survey is shown in Table 5-5. The gates experienced two failures over more than 20,000 transactions for an MTF rate of 10,299. The lower bound of the 95 percent confidence interval was 4,320. The MTBF rate was 91.1 hours as shown in Table 5-6.

Vendors - Property-Supplied Data

The reliability measures for vendors in the Tyne and Wear Metro for April and May 1981 are shown in Tables 5-7 and 5-8, respectively. These measures are based on failures that do not include those resulting from vandals. Because of data limitations, sample sizes for some stations have been extrapolated from known MTF rates and failure counts.

Table 5-7 shows the April figures for each station. The overall system vendor MTF rate was 7,087. The 95 percent

TABLE 5-2. TYNE & WEAR VENDORS - RELIABILITY BY STATION - ON-SITE SURVEY

STATION	NO. OF VENDORS	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
Haymarket	7	.999804	5,111	10,222	2
Monkseaton	4	1.00	1,308/0	1,308	0
Whitley Bay	5	1.00	1,055/0	1,055	0
Regent Centre	3	.999350	1,538	1,538	1
Sample Total	19	.999789	4,708 (2,219)*	14,123	3

*95% confidence interval lower bound of sample MTF.

TABLE 5-3. TYNE & WEAR VENDORS - RELIABILITY BY VENDOR - ON-SITE SURVEY

STATION	VENDOR ID	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
Haymarket	03	1.00	1,657/0	1,657	0
	05	1.00	1,362/0	1,362	0
	08	.999423	1,733	1,733	1
	49	1.00	1,236/0	1,236	0
	54	.999455	1,835	1,835	1
	55	1.00	1,535/0	1,535	0
	59	1.00	864/0	864	0
Monkseaton	02	1.00	154/0	154	0
	06	1.00	522/0	522	0
	07	1.00	172/0	172	0
	11	1.00	460/0	460	0
Whitley Bay	01	1.00	277/0	277	0
	04	1.00	157/0	157	0
	12	1.00	319/0	319	0
	21	1.00	62/0	62	0
	58	1.00	240/0	240	0
Regent Centre	27	1.00	287/0	287	0
	20	1.00	563/0	563	0
	33	.998547	688	688	1
Sample Total		.999789	4,708	14,123	3

TABLE 5-4. TYNE AND WEAR VENDORS - MEAN TIME BETWEEN FAILURES BY STATION - ON-SITE SURVEY

STATION	NO. OF VENDORS	TOTAL IN-SERVICE TIME (MACHINE HOURS)	TOTAL FAILURES	MTBF
Haymarket	7	79.6	2	39.8
Monkseaton	4	38.9	0	No Failures
Whitley Bay	5	60.0	0	No Failures
Regent Centre	3	36.7	1	37.7
Sample Total	19	215.2	3	71.7

TABLE 5-5. TYNE AND WEAR GATES - RELIABILITY BY STATION - ON-SITE SURVEY

STATION	NO. OF GATES	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
Haymarket	5	.999934	15,210	15,210	1
Monkseaton	4	.999479	1,920	1,920	1
Whitley Bay	4	1.00	1,465/0	1,465	0
Regent Centre	3	1.00	2,002/0	2,002	0
Sample Total	16	.999903	10,299 (4,320)*	20,597	2

*95% confidence interval lower bound of sample MTF.

TABLE 5-6. TYNE AND WEAR GATES - MEAN TIME BETWEEN FAILURES BY STATION - ON-SITE SURVEY

STATION	NO. OF GATES	TOTAL IN-SERVICE TIME (MACHINE HOURS)	TOTAL FAILURES	MTBF
Haymarket	5	55.7	1	55.7
Monkseaton	4	42.5	1	42.5
Whitley Bay	4	47.7	0	No Failures
Regent Centre	3	36.3	0	No Failures
Sample Total	16	182.2	2	91.1

TABLE 5-7. TYNE & WEAR VENDORS - RELIABILITY BY STATION - APRIL 1981

STATION	NO. OF VENDORS	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
Haymarket	7	.999897	9,677	164,517	17
Monkseaton	4	.999821	5,576	33,458	6
Whitley Bay	5	.999672*	3,046	48,734	16
Jesmond	2	.999908	10,859	21,719	2
W. Jesmond	4	.999948	19,054	38,108	2
Ilford Rd.	4	.999717	3,530	7,059	2
So. Gosforth	4	.999862	7,270	29,079	4
Longbenton	4	.999856	6,946	27,785	4
Four Lane Ends	3	.999906	10,601	31,802	3
Benton	4	.999832	5,957	17,871	3
Shiremoor	4	.999874	7,922	23,766	3
W. Monkseaton	2	.999771	4,359	17,434	4
Cullercoats	4	.999739	3,827	19,136	5
Tynemouth	2	1.00	22,701/0	22,701	0
System Total	53	.999859	7,087 (5,750, 9,235)**	503,169	71

*Station with reliability significantly below system total at 95% confidence level.

**MTF in parentheses indicates 95% confidence interval.

TABLE 5-8. TYNE & WEAR VENDORS - RELIABILITY BY STATION - MAY 1981

STATION	NO. OF VENDORS	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
Haymarket	7	.999899	9,856	206,968	21
Monkseaton	4	.999548*	2,213	35,406	16
Whitley Bay	5	.999841	6,306	56,754	9
Regent Centre	3	.999683	3,155	25,242	8
Jesmond	2	.999963	26,971	26,971	1
W. Jesmond	4	.999933	15,002	30,005	2
Ilford Rd.	4	.999762	4,205	8,410	2
So. Gosforth	4	.999972	35,162	35,162	1
Longbenton	4	.999786	4,675	28,047	6
Four Lane Ends	3	1.00	34,768/0	34,768	0
Benton	4	.999467*	1,876	15,012	8
Shiremoor	4	.999701	3,347	23,429	7
W. Monkseaton	2	1.00	17,375/0	17,375	0
Cullercoats	4	.999691	3,231	22,620	7
Tynemouth	2	.999850	6,671	26,685	4
Wansbeck Rd.	4	.999431*	1,756	14,050	8
Fawdon	3	.999639	2,770	22,163	8
Bankfoot	2	.999889	8,977	17,954	2
System Total	65	.999830	5,882 (4,956, 7,234)**	647,021	110

*Stations with reliability significantly below system total at 95% confidence level.

**MTF in parentheses indicates 95% confidence interval.

confidence interval was 5,750-9,235. Whitley Bay displayed an MTF of 3,046, significantly below the system MTF at the 95 percent confidence level.

Table 5-8 presents the same information for May 1981. The system average dropped to an MTF of 5,882, partially due to the performance of the vendors at Wansbeck Road, one of four stations put on-line for AFC equipment in May.

Three stations exhibited MTF rates significantly below the system MTF at the 95 percent confidence level. These were Monkseaton (2,213), Benton (1,876), and Wansbeck Road (1,756). The 95 percent confidence interval for the system MTF was 4,956-7,234.

Combining the data for the two months results in the performance measures shown in Table 5-9. The two-month system total MTF was 6,908 with a 95 percent confidence interval of 5,969-8,198. (Note that the four stations which began AFC operation in May have not been included in the table.) Four stations, Monkseaton (3,130), Benton (2,989), Whitley Bay (4,220) and Cullercoats (3,480) had MTF rates significantly below the system MTF at the 95 percent confidence level.

Magnetic Ticket Issuer/Reader Subsystem

The data related to the magnetic ticket issuer/reader were compiled at the system level and reliabilities for April and May were generated. In April, as shown in Table 5-10, MTF was 14,799 for the 53 vendors in the system. For the same machines in May, the MTF was 13,844, a seven percent decline. The decrease was not found to be statistically significant. The two-month average was 14,277. When all 65 machines were considered, the May MTF for the subsystem was 14,379 and the two-month total was 14,559.

TABLE 5-9. TYNE & WEAR VENDORS - RELIABILITY BY STATION - APRIL AND MAY 1981

STATION	NO. OF VENDORS	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
Haymarket	7	.999898	9,776	371,485	38
Monkseaton	4	.999681*	3,130	68,864	22
Whitley Bay	5	.999763*	4,220	105,488	25
Jesmond	2	.999938	16,230	48,690	3
W. Jesmond	4	.999941	17,028	68,113	4
Ilford Rd.	4	.999741	3,867	15,469	4
So. Gosforth	4	.999922	12,848	64,241	5
Longbenton	4	.999821	5,583	55,832	10
Four Lane Ends	3	.999955	22,190	66,570	3
Benton	4	.999666*	2,989	32,883	11
Shiremoor	4	.999788	4,720	47,195	10
W. Monkseaton	2	.999885	8,702	34,809	4
Cullercoats	4	.999713*	3,480	41,756	12
Tynemouth	2	.999919	12,346	49,386	4
System Total	53	.999855	6,908 (5,969, 8,199)**	1,070,781	155

*Stations with reliability significantly below system total at 95% confidence level.

**MTF in parentheses indicates 95% confidence interval.

TABLE 5-10. TYNE & WEAR VENDORS - SYSTEM RELIABILITY OF MAGNETIC TICKET ISSUER/ READER SUBSYSTEM - APRIL AND MAY 1981

PERIOD	NO. OF VENDORS	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
April	53	.999932	14,799	503,169	34
May	53	.999928	13,844	567,612	41
April-May Total*		.999930	14,277 (11,649, 18,466)**	1,070,781	75
May (All Vendors)	65	.999930	14,379	647,021	45
April-May Total***		.999931	14,559 (11,879, 18,581)**	1,150,190	79

*Excluding 12 vendors at stations coming on-line in May 1981.
**MTF in parenthesis indicates 95 percent confidence interval.
***Including the new vendors.

5.3.2 Tyne and Wear AFC Availability

Availability measures were generated based on the on-site survey data. Data presented by the property did not contain equipment downtimes, preventing availability analysis on property-supplied data.

Vendors

Table 5-11 summarizes the availability by station for the Tyne and Wear vendors. Vendor availability was 99.60 percent based on more than 215 hours of machine operation. (Note that four failures are shown for vendors. This is one more than those shown for reliability. This is because one failure occurred before a survey period but affected the availability of the machine during the survey period.)

Gates

As Table 5-12 shows, the gates were slightly more available than the vendors. Gate availability was 99.76 percent based on more than 182 hours of machine operation.

5.3.3 Tyne and Wear AFC Maintainability

Of the four failures observed, one affected the time of issue printed on the ticket. Tickets were being vended with erroneous time data. The time on a ticket was a day ahead of the actual time. (Note that the tickets were accepted at the gates.) The downtime associated with this failure was all active repair time by the technician, who spotted the failure at the beginning of a survey period while taking a transaction reading.

TABLE 5-11. TYNE & WEAR VENDORS - AVAILABILITY BY STATION - ON-SITE SURVEY

STATION	NO. OF VENDORS	AVAILABILITY (PERCENT)	SAMPLE SIZE (MINUTES)	FAILURES
Haymarket	7	99.60	4,795	3
Monkseaton	4	100.00	2,332	0
Whitley Bay	5	100.00	3,600	0
Regent Centre	3	98.52	2,235	1
Sample Total	19	99.60	12,962	4

TABLE 5-12. TYNE & WEAR GATES - AVAILABILITY BY STATION - ON-SITE SURVEY

STATION	NO. OF GATES	AVAILABILITY (PERCENT)	SAMPLE SIZE (MINUTES)	FAILURES
Haymarket	5	99.85	3,350	1
Monkseaton	4	99.18	2,572	1
Whitley Bay	4	100.00	2,860	0
Regent Centre	3	100.00	2,175	0
Sample Total	16	99.76	10,957	2

The four vendor failures put the machines out-of-service or unavailable for a total of 52 minutes for an ADT of 13 minutes. The average time to repair was nine minutes.

For the gates, the two failures put the machine out-of-service or unavailable for 26 minutes, an average of 13 minutes per failure. Total active repair time was six minutes. For both types of equipment, no hard failures occurred, hence no MTTR measures were computed. Section 6 provides more information on the repair of failures.

5.4 STUTTGARTER STRASSENBAHNEN RESULTS

On-site data were collected on 10 SSB vendors located at the system's central station (Hauptbahnhof) for the 5-day period, 27 July - 31 July. Data were collected for a total of approximately 15 hours per machine. In addition to the survey data, SSB provided a variety of transaction, failure, and maintenance data for analysis purposes. These data were:

- Reliability measures for the system as a whole by month, from 1/80 - 6/81;
- Distribution of system failures by type and by month 1/81 - 6/81;
- Monthly transaction data from 1/81 - 6/81 for selected vendors. The selected vendors were all vendors at Hauptbahnhof and four vendors at Mohringen-Bahnhof, an outdoor transfer station;
- Full maintenance records for the selected vendors;
- Maintenance intervention sheets for the surveyed vendors for the entire survey week.

5.4.1 SSB AFC Reliability

On-Site Data

Table 5-13 presents the results of the on-site data for the 10 vendors observed at the Hauptbahnhof. During the survey, a total of three failures occurred over 5,464 transactions for an MTF of 1,821 with a lower bound of 855. All three failures occurred at vendor #316, which had an MTF of 135, based on 406 transactions. The MTF for #316 was not found to be significantly below the sample total at the 95 percent confidence level. MTBF measures were also computed for the surveyed vendors. The MTBF measure for the sample data was 45.3 hours.

Five-Day Data on Surveyed Machines

Because all maintenance intervention sheets were made available, it was possible to estimate reliabilities for the observed machines, based on all tickets vended between Monday, 25 July and Friday, 31 July, 1981. Table 5-14 presents the results of the reliability measures for these data. Based on 16,265 transactions, the sample MTF was 2,711. Vendor #316 had an MTF of 270, which was found to be significantly below the sample average at the 95 percent confidence level. The 95 percent confidence interval for the sample total was 1,506-13,555. Since equipment downtimes were not available, MTBF measures were not computed.

Property-Supplied Data - Selected Vendors

Six-month reliability measures were generated for vendors at two stations, based on a review of six-month transaction summaries and the maintenance records of each vendor. Vandal failures were not included. The performance of 16 vendors located inside the Hauptbahnhof station and six outdoor vendors - four at Mohringen-Bahnhof, and two outside the Hauptbahnhof

TABLE 5-13. SSB VENDORS - RELIABILITY BY VENDOR - ON-SITE SURVEY

STATION	VENDOR ID	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
Hauptbahnhof	107	1.00	279/0	279	0
	108	1.00	301/0	301	0
	109	1.00	638/0	638	0
	110	1.00	825/0	825	0
	111	1.00	589/0	589	0
	316	.992611	135	406	3
	317	1.00	456/0	456	0
	458	1.00	1,099/0	1,099	0
	516	1.00	700/0	700	0
	590	1.00	111/0	111	0
Sample Total		.999451	1,821 (855)*	5,464	3

*95% confidence interval lower bound of MTF.

TABLE 5-14. SSB VENDORS - RELIABILITY BY VENDOR - SURVEYED VENDORS - WEEK OF 7/27 - 7/31

STATION	VENDOR ID	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
Hauptbahnhof	107	1.00	651/0	651	0
	108	1.00	779/0	779	0
	109	.999256	1,344	1,344	1
	110	.999421	1,726	1,726	1
	111	1.00	2,360/0	2,386	0
	316	.996302*	270	1,352	4
	317	1.00	1,485/0	1,485	0
	458	1.00	3,938/0	3,938	0
	516	1.00	2,184/0	2,184	0
	590	1.00	420/0	420	0
Sample Total		.999631	2,711 (1,506, 13,555)**	16,265	6

*Vendor with MTF significantly below sample total at 95% confidence level.

**MTF in parentheses indicates 95% confidence interval.

station - were analyzed. The vendors were broken up into two groups, indoor and outdoor in order to determine if significant performance differences might exist due to environmental conditions. The six-month time frame covered the winter and spring of 1981.

Table 5-15 presents the reliability for the indoor vendors. Forty-seven failures were determined from the maintenance records of these machines which vended just under 1 million tickets during the six-month period. The MTF rate was 21,214 and the 95 percent confidence interval was 16,497-29,707.

On the other hand, as shown in Table 5-16, the MTF for the six outdoor vendors (two of which are located outside Hauptbahnhof), was 14,593, with a 95 percent confidence interval of 9,320-33,607. A t-test indicated that the difference between the indoor and outdoor vendors was not significant at the 95 percent level.

Property-Supplied Data - Full System

A series of reliability tables for the SSB system are presented below. The tables differ according to the types of failures used for the reliability measure. This was possible since SSB categorizes failures in several ways. The key category is technical failures which are defined as malfunctions of functional subsystems or components. Other categories are:

- Administrative failures (e.g., no paper, full cash box);

- Vandal failures, i.e., vandal-related failures;

TABLE 5-15. SSB VENDORS - RELIABILITY FROM 1/81 - 6/81 - INDOOR VENDORS

VENDOR ID	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
103	.999955	22,254	66,761	3
104	.999943	17,636	70,542	4
105	.999828	5,802	23,206	4
106	.999900	9,974	49,869	5
107	.999899	9,871	19,741	2
108	1.00	20,512/0	20,512	0
109	.999925	13,417	40,252	3
110	.999912	11,336	45,344	4
111	.999942	17,140	102,838	6
112	.999911	11,190	33,571	3
314	.999972	35,531	106,592	3
315	.999969	31,772	95,315	3
316	1.00	69,923/0	69,923	0
317	1.00	68,094/0	68,094	0
458	.999967	30,606	153,031	5
459	.999936	15,733	31,466	2
Sample Total	.999953	21,214 (16,497, 29,707)*	997,057	47

*MTF in parentheses indicates 95% confidence interval.

TABLE 5-16. SSB VENDORS - RELIABILITY FROM 1/81 - 6/81 - OUTDOOR VENDORS

VENDOR ID	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
214	1.00	22,831/0	22,831	0
215	.999707	13,631/0	13,631	0
216	.999876	8,035	32,141	4
217	.999794	4,847	14,541	3
516	.999973	37,079	74,158	2
590	.999832	5,937	17,812	3
Sample Total	.999931	14,593 (9,320, 33,607)*	175,114	12

*MTF in parentheses indicates 95% confidence interval.

- Wrong information, i.e., patron phone calls that require a technician to investigate, but result in no failure being found;

- "Other" failures. These were classified into six subcategories. Four cover adjustments, replacements and repairs on the following peripheral equipment:

  - Service voltage;
  - Service indicator;
  - Plugs and cables;
  - Return cup (including flap, foreign material channel, coin box channel, and information panel);

  The last two subcategories are:

  - Removal of damaged coins; and
  - Cleaning of the machine after a failure.

Reliability figures based only on technical failures were generated for 1980. In addition, a series of system reliabilities were computed for the first six months of 1981, based on the various categories of failures.

Table 5-17 indicates that during 1980, based on over 15 million tickets sold, the SSB system experienced an MTF of 14,042, with 1,107 technical failures. The 95 percent confidence interval was 13,300 - 14,968. Two months, June and August, had MTF's significantly below the yearly total at the 95 percent confidence level.

Table 5-18 presents the same performance data for the first six months of 1981. The system MTF rate, based on over 7.3 million transactions, was 12,728, roughly a 10 percent decline in system performance from 1980, but only 2.7 percent below the system total for the same six-month period in 1980, when the system MTF rate was 13,080.

TABLE 5-17. SSB VENDORS - 1980 SYSTEM RELIABILITY BY MONTH - BASED ON TECHNICAL FAILURES ONLY

MONTH/YR	TOTAL VENDORS	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
1/80	489	.999926	13,434	1,249,395	93
2/80	489	.999931	14,449	1,213,698	84
3/80	490	.999917	12,082	1,232,350	102
4/80	490	.999923	13,058	1,266,650	97
5/80	490	.999930	14,226	1,294,580	91
6/80	488	.999914*	11,670	1,225,368	105
7/80	487	.999918	12,267	1,361,652	111
8/80	489	.999904*	10,407	1,144,749	110
9/80	489	.999937	15,755	1,370,667	87
10/80	488	.999950	19,804	1,465,464	74
11/80	487	.999942	17,270	1,191,689	69
12/80	487	.999945	18,199	1,528,693	84
Total 1980	489	.999929	14,042 (13,300, 14,968)**	15,544,955	1,107

*Monthly system reliability significantly below 1980 system average as 95% confidence level.

**MTF in parentheses indicates 95% confidence interval.

TABLE 5-18. SSB VENDORS - 1981 SYSTEM RELIABILITY BY MONTH - BASED ON TECHNICAL FAILURES ONLY

MONTH/YR	TOTAL VENDORS	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
1/81	487	.999926	13,527	1,136,232	84
2/81	485	.999927	13,785	1,144,122	83
3/81	484	.999923	12,926	1,266,779	98
4/81	484	.999921	12,701	1,257,446	99
5/81	485	.999900*	10,010	1,261,252	126
6/81	485	.999932	14,695	1,278,453	87
Total 1/81-6/81		.999921	12,728 (11,768, 13,859)**	7,344,284	577

*Monthly system reliability significantly below 6-month system average at 95% confidence level.

**MTF in parentheses indicates 95% confidence interval.

During 1981, only May had an MTF significantly below the half-year total at the 95 percent confidence level. The 95 percent confidence interval of the system six-month MTF rate was 11,768 - 13,859.

The remainder of the tables presented for SSB show the reliability of the equipment, based on different failure counts for the first six months in 1981.

Table 5-19 shows the system reliability based on all failures. The system MTF was 3,311 and the 95 percent confidence interval was 3,178 - 3,455. Table 5-20 shows the same MTF computations based on failures other than vandal and administrative failures. The system MTF increased to 4,178 with a 95 percent confidence interval of 3,997 - 4,389.

When technical failures plus four subcategories of the "other" failure category were included, the MTF rate increased to 6,948 with a 95 percent confidence interval of 6,550 - 7,390 as shown in Table 5-21. The four subcategories selected were those that represented failures in peripheral equipment.

Printer Reliability

Table 5-22 presents the monthly reliabilities for the needlepoint printers based on technical failures. The six-month MTF rate was 32,496 based on over 7 million tickets sold. The confidence interval was 28,550 - 37,874.

5.4.2 SSB AFC Availability

Availability was measured for the ten vendors observed during the on-site survey. As Table 5-23 indicates, the sample average was 99.98 percent, based on 136 machine hours of operation. Availability measures were not generated for the full week because initial downtimes were not available.

TABLE 5-19. SSB VENDORS - 1981 SYSTEM RELIABILITY BY MONTH - BASED ON ALL FAILURES

MONTH/YR	TOTAL VENDORS	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
1/81	487	.999603*	2,519	1,136,232	451
2/81	485	.999703	3,365	1,144,122	340
3/81	484	.999714	3,499	1,266,779	362
4/81	484	.999722	3,593	1,257,446	350
5/81	485	.999687	3,193	1,261,252	395
6/81	485	.999750	3,995	1,278,453	320
Total 1/81-6/81	485	.999698	3,311 (3,178, 3,455)**	7,344,284	2,218

*Monthly system reliability significantly below 6-month system average at 95% confidence level.

**MTF in parentheses indicates 95% confidence interval.

TABLE 5-20. SSB VENDORS - 1981 SYSTEM RELIABILITY BY MONTH - EXCLUDING VANDAL AND ADMINISTRATIVE-RELATED FAILURES

MONTH/YR	TOTAL VENDORS	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
1/81	487	.999716*	3,518	1,136,232	323
2/81	485	.999759	4,145	1,144,122	276
3/81	484	.999773	4,414	1,266,779	287
4/81	484	.999780	4,540	1,257,446	277
5/81	485	.999734*	3,765	1,261,252	335
6/81	485	.999797	4,917	1,278,453	260
Total 1/81-6/81	485	.999761	4,178 (3,997, 4,389)**	7,344,284	1,758

*Monthly system reliability significantly below 6-month system average at 95% confidence level.

**MTF in parentheses indicates 95% confidence interval.

TABLE 5-21. SSB VENDORS - 1981 SYSTEM RELIABILITY BY MONTH - BASED ON TECHNICAL FAILURES PLUS SELECTED OTHER FAILURES*

MONTH/YR	TOTAL VENDORS	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
1/81	487	.999826**	5,738	1,136,232	198
2/81	485	.999858	7,019	1,144,122	163
3/81	484	.999855	6,884	1,266,779	184
4/81	484	.999871	7,762	1,257,446	162
5/81	485	.999838	6,181	1,261,252	204
6/81	485	.999886	8,753	1,278,453	146
Total 1/81-6/81	485	.999856	6,948 (6,550, 7,390)***	7,344,284	1,057

*"Other" failures include adjustments, replacements and repairs on the following:

Service Voltage,
Plugs & Cable,
Service Indicator, and
Return Cup

**Monthly system reliability significantly below 6-month system average at 95% confidence level.

***MTF in parentheses indicates 95% confidence interval.

TABLE 5-22. SSB VENDORS - 1981 SYSTEM PRINTER RELIABILITY BY MONTH

MONTH/YR	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
1/81	.999975	40,580	1,136,232	28
2/81	.999972	35,754	1,144,122	32
3/81	.999967	30,161	1,266,779	42
4/81	.999967	30,669	1,257,446	41
5/81	.999962	26,276	1,261,252	48
6/81	.999973	36,527	1,278,453	35
Total 1/81-6/81	.999969	32,497 (28,550 37,074)*	7,344,284	226

*MTF in parentheses indicates 95% confidence interval.

TABLE 5-23. SSB VENDORS - AVAILABILITY BY VENDOR - ON-SITE SURVEY

STATION	VENDOR ID	AVAILABILITY (PERCENT)	SAMPLE-SIZE (MINUTES)	FAILURES
Hauptbahnhof	107	100.00	840	0
	108	100.00	840	0
	109	100.00	720	0
	110	100.00	720	0
	111	100.00	840	0
	316	99.74	840	3
	317	100.00	840	0
	458	100.00	840	0
	516	100.00	840	0
	590	100.00	840	0
Sample Total		99.98	8,160	3

5.4.3 SSB AFC Maintainability

Maintainability measures for the on-site survey were not generated due to the fact that repair of one failure took place after the survey period and the other two required minor adjustments that, in fact, did not fix the problem. The problem was eventually taken care of by removal of the printer. Section 6 provides more information on this matter.

SSB provided the maintenance reports for the surveyed machines for the week of July 27-31. The maintainability information was available only in terms of active repair or replacement times. Table 5-24 summarizes the failure and the active repair/replacement time.

For the full system, SSB provided data by month on the amount of time maintenance men worked on failures, both in the shop and in the field. In addition, figures were available for the amount of time spent travelling to and from vendors. Table 5-25 presents these data.

5.5 RATP RESULTS

5.5.1 RATP AFC Reliability

Due to the inability of the authority to provide transaction data, reliability measures could not be generated. However, Section 6 provides a discussion of the failures observed by IOCS surveyors during the survey periods.

Discussions with property personnel indicated that for the CAMP/CGA gates, mean transactions per maintenance action measures were roughly 50,000. This figure did not include jams that were cleared by the ticket agents, either manually or by

TABLE 5-24. SSB VENDORS - FAILURES OF SURVEYED VENDORS - 7/27-7/31

VENDOR ID	DESCRIPTION OF FAILURE/ACTION TAKEN	ACTIVE REPAIR TIME
109	Defective cable - replaced	10 min.
110	1 DM coins jammed in coin drum	15 min.
316	Loose plug - tightened*	10 min.
316	Printer changed, control for ticket-cutting was adjusted**	10 min.

*Machine was randomly printing more than one ticket at a time. The technician adjusted the paper twice while on-site survey took place. When it became clear that these adjustments did not fix the machine, the technician then tightened a loose plug.

**The printer change took place because the machine was still randomly printing too many tickets.

TABLE 5-25. SSB SYSTEM MAINTAINABILITY DATA BY MONTH

MONTH/YR	TOTAL OF ALL FAILURES	MAN-HOURS SPENT PER FAILURE	MAN-HOURS SPENT TRAVELLING TO FAILURE	AVERAGE DISTANCE COVERED PER FAILURE (KILOMETERS)
1/80	529	0.2	0.24	10.03
2/80	379	0.19	0.38	11.32
3/80	389	0.17	0.4	11.38
4/80	346	0.18	0.38	11.94
5/80	348	0.18	0.44	11.8
6/80	352	0.19	0.48	11.1
7/80	367	0.18	0.55	11.8
8/80	311	0.2	0.55	13.01
9/80	323	0.19	0.5	11.74
10/80	334	0.19	0.5	11.45
11/80	271	0.19	0.54	13.23
12/80	354	0.2	0.47	11.86
1/81	451	0.19	0.36	10.8
2/81	340	0.18	0.56	12.3
3/81	362	0.2	0.55	12.2
4/81	350	0.18	0.53	12.4
5/81	395	0.18	0.49	11.8
6/81	320	0.18	0.56	13.1

the automatic jam-clearing device. For the recently installed Crouzet gates, the reliability initially was approximately 20,000 and was currently averaging about 60,000. RATP officials are expecting the reliability to increase to 90,000.

5.5.2 RATP AFC Availability

Vendors

Availability was measured for the 13 vendors observed during the on-site survey. As shown in Table 5-26, vendor availability was 88.45 percent based on 88 hours of machine operation. All except two vendors at Chatalet Les Halles were in-service for the entire survey period. Vendor #300080, a 1969 Crouzet machine, and vendor #V1, an experimental Crouzet vendor, were out-of-service for about half the survey period.

Gates

The availability for the 47 gates surveyed was 98.03 percent as shown in Table 5-27. Availability figures were based on more than 288 hours of machine operation.

5.5.3 RATP AFC Maintainability

Maintainability of equipment was difficult to gauge because maintenance and failure data were not available from the property. On-site repairs observed by IOCS surveyors included gate repair only. For the CAMP/CGA gates, one hard failure occurred that required the replacement of the tripod barrier and associated equipment. Active repair by two technicians was approximately one hour, part of which was spent identifying the problem. For the Crouzet gates used on the RER, a logic problem required a new PCB. Diagnostic testing of the old

TABLE 5-26. RATP VENDORS - AVAILABILITY BY VENDOR - ON-SITE SURVEY

STATION	VENDOR ID	AVAILABILITY (PERCENT)	SAMPLE SIZE (MINUTES)
Chatalet Les Halles*	300080	50.41	605
	300307	100.00	605
	300308	100.00	605
	300384	100.00	605
	V1	50.41	605
	V2	100.00	605
Gare Du Nord**	V1	100.00	375
	V2	100.00	375
Gare De Lyon (Metro)**	V1	100.00	180
	V2	100.00	180
	V3	100.00	180
	V4	100.00	180
	V5	100.00	180
SAMPLE TOTAL		88.45	5,280

*V1 and V2 were new Crouzet vendors.
**Vendors at these mezzanines were Marcel Dessault machines.

TABLE 5-27. RATP GATES - AVAILABILITY BY MEZZANINE - ON-SITE SURVEY

MEZZANINE	NO. OF GATES	AVAILABILITY (PERCENT)	SAMPLE SIZE (MINUTES)
Chatalet Les Halles	10	100.00	4,650
Gare Du Nord	15	99.02	5,625
Gare De Lyon (Metro)	11	90.90	1,980
Gare De Lyon (RER)	21*	97.92	5,040
SAMPLE TOTAL	57	98.03	17,295

*Crouzet transporters

board and its replacement required 40 minutes. Other downtimes were due to ticket jams that were usually attended by station agents or cleared by the automatic jam-clearing device.

6. PERFORMANCE ANALYSIS

An assessment of AFC equipment failures is helpful in two ways. First, the assessment can indicate the most frequent types of problems and the subsystems and components affected. In addition, where statistical tests have indicated that performance measures differ, a failure analysis can suggest reasons for the differences. Accordingly, this section presents descriptions and distributions of failures from available data, and analyzes the performance measures presented in the previous section with respect to the data.

6.1 TYNE AND WEAR METRO

For Tyne and Wear, the analysis of performance includes an examination of individual vendors at those stations that displayed reliabilities statistically below the system total.

6.1.1 Analysis of Surveyed Equipment

During the survey of the Tyne and Wear AFC equipment, IOCS surveyors observed a total of four failures for the vendors and two failures for the gates. Two of the vendor failures occurred before a survey period but were repaired by technicians during the period. Table 6-1 lists the vendor failures observed and the active repair times.

For the vendors, one of the two failures that occurred during the survey (vendor #33 at Regent Centre) was probably due to the delivery pinch rollers of the ticket transport being out of adjustment. This resulted in tickets getting jammed at this point and not being dropped into the escrow box for delivery to the patron. In addition, the machine went out of

TABLE 6-1 SUMMARY OF TYNE AND WEAR VENDOR FAILURES - ON-SITE SURVEY

STATION	VENDOR ID	FAILURE	ACTIVE REPAIR TIME (MINUTES)
Haymarket	8	Coin jam in 1 Pence cassette.	10
	54	Ticket jam at delivery pinch roller.	5
	55	Incorrect time on clock.	4
Regent Centre	33	Ticket jam at delivery pinch roller.	18

TABLE 6-2 SUMMARY OF TYNE AND WEAR GATE FAILURES - ON-SITE SURVEY

STATION	GATE ID	FAILURE	ACTIVE REPAIR TIME (MINUTES)
Haymarket	44885	Randomly not reading valid tickets due to dirt/dust accumulation around a sensor.	5
Monkseaton	45083	Ticket jam.	1

service. For the other failure (vendor #54 at Haymarket), the machine did not deliver a ticket but kept the patron's money. The machine then delivered two tickets to the next patron. Tyne and Wear officials suggested that the fault was due to static, causing a ticket to remain in the escrow with the flap open. The first repair took five minutes. The technician adjusted the rollers, cleaned the area around them, and made some test tickets. The second repair took 18 minutes because the technician made some extra adjustments.

The two remaining vendor failures were a coin jam in the 1 Pence cassette and a clock with the incorrect time. The former put the machine out of service because the cassette was not able to spin properly. Ten minutes were required to remove the coin. The clock problem resulted in tickets being printed with the next day's date. A mobile inspector had notified the control center which in turn informed an AFC technician. The machine, which was not out of service, was repaired in four minutes.

In addition to these failures, surveyors observed several occurrences for the vendors. All occurrences were related to the coin selector. Vendors at Monkseaton were observed rejecting a few coins. At Regent Centre, one vendor accepted a coin that another vendor had twice rejected. In both situations, it was not possible to determine the condition or the type of the coins inserted. In any case, the number of occurrences was minimal.

Table 6-2 presents the two failures that occurred at the Tyne and Wear gates during the survey. The first failure was due to the accumulation of dirt around one of the sensors in the transport (gate #44885 at Haymarket). This resulted in valid tickets intermittently not being accepted. In some cases, the tickets were accepted on the second attempt; in

other cases, the patron moved to another gate and was allowed entry. A technician, who was on-site at the time, observed this situation, put the machine out of service, cleaned the area around the sensor, tested the transport with his employee pass, and put the gate back in service. The repair time was five minutes.

The second failure was a ticket jam (gate #45083 at Monkseaton). The gate went out of service. When the technician arrived, he cleared the jam in one minute and stated that the failure was due to the bent condition of the ticket.

Six occurrences were observed for the gates - all at Haymarket. These were the result of valid cards not being read properly upon first insertion. In the cases observed, which occurred during queues, the patron entered the system on the valid ticket of the next patron. By the time that the second patron got to the barrier, it was locked. Discussions with technicians and inspectors suggested that the situation resulted from dirt or dust accumulation around critical parts of the transport and monthly and special tickets wearing down from extensive use.

6.1.2 Analysis of Performance Measures Based on Property-Supplied Data

Table 5-7 indicated that for April 1981 the system MTF for Tyne and Wear vendors was 7,087 based on 503,169 tickets vended and 71 failures. Table 6-3 presents the distribution of the system failures by subsystem affected while Table 6-4 presents the failures by failure type. As shown in Table 6-3, of the 71 failures recorded, 34 (or 48 percent) occurred in the magnetic ticket issuer/reader subsystem. As shown in the next table, the majority of these failures (21) were sensors not changing state, i.e., position. In fact, these failures

TABLE 6-3 DISTRIBUTION OF TYNE AND WEAR APRIL 1981 VENDOR FAILURES BY SUBSYSTEM AFFECTED

SUBSYSTEM	NUMBER OF FAILURES	PERCENT OF TOTAL
Magnetic Ticket Issuer/Reader	34	47.9
Coin Recycling Subsystem	20	28.2
Coin Selector	6	8.5
Vault	5	7.0
Logic/PC Boards	3	4.2
Clock	2	2.8
Miscellaneous	1	1.4
TOTAL	71	100.0

TABLE 6-4 DISTRIBUTION OF TYNE AND WEAR APRIL 1981 VENDOR FAILURES BY TYPE

FAILURE TYPE	NUMBER	PERCENT OF TOTAL
Cutter sensor not blocked	3	4.2
Sensors in ticket transport do not change state	21	29.6
Speed variation of encoder motor	1	1.4
Failure to verify (encoding failure)	2	2.8
Printer sensors in incorrect state before transaction	1	1.4
Fault in new strip feed contact	6	8.5
Coin in cassette not identical to coin viewed by selector	1	1.4
Coin in cassette not viewed as correct by selector	1	1.4
Coin viewed by selector but not by cassette	7	9.9
Cassette entry cell still blocked	1	1.4
Cassette motor has not started up	1	1.4
Cassette Cam not at rest after rotation command	2	2.8
Coin sent to vault when cassette not full	1	1.4
Cell on cassette exit towards vault still blocked	3	4.2
Cell on cassette exit towards return cup blocked	3	4.2
Selector slot jammed or sticking	4	5.6
Coin selector rejecting all coins	1	1.4
Coin selector replaced	1	1.4
Missing Vault	5	7.0
Input/Output board replaced	1	1.4
CPU replaced	1	1.4
Fare selection board replaced	1	1.4
Incorrect time on clock	2	2.8
Time-out triggered	1	1.4
TOTAL	71	99.8*

*Rounding error.

represented 30 percent of all failures. The sensors supply information to the microprocessor which controls the passage of the ticket through the cutter, printer and encoder. If a sensor does not change state, the next transaction cannot be completed. In addition to the sensor failures, six failures were recorded for the new strip feed contact that facilitates the use of the second roll of ticket paper. With respect to the encoding function, two failures to verify were recorded.

Table 6-3 also indicates that for the coin recycling subsystem, 20 failures (28 percent of the total) were recorded in April. Table 6-4 indicates that of the 20, seven were failures resulting from coins being viewed or registered by the coin selector, but not by the appropriate cassette. Of the other failures related to the recycling subsystem, six were due to the exit cells of the coin cassettes being blocked, i.e., jammed, preventing coins from dropping into either the vault or the return cup.

With respect to coin selectors, four instances of selectors being jammed and one instance of a selector rejecting all coins were recorded. The latter selector was eventually replaced.

Of the 71 April vendor failures, 16 (or 23%) occurred at Whitley Bay, the only station with an MTF (3,046) significantly below the system total at the 95 percent confidence level. In April, Whitley Bay vended approximately 10 percent of the tickets sold in the Tyne and Wear system. Eight of the 16 failures occurred at one machine (vendor #21). Three of the eight failures were related to the coin selector and four were related to the coin recycling subsystem. The selector failures were a coin jam and two failures mentioned above, i.e., rejection of all coins, and eventual replacement of the selector. The failures of the recycling subsystem involved the cassette not viewing coins that were viewed by the selector. The individual vendor MTF rates were as follows: 14,157 (#12),

7,451 (#1), 3,717 (#58), 3,391 (#4) and 236 (#21). The reliability of vendor #21 was found to be significantly below the system total at the 95 percent confidence level.

Tyne and Wear vendor system MTF for May 1981 when four more stations came on-line, was 5,882, based on 647,021 tickets vended and 110 failures. The decline of 17 percent in system performance was not found to be significant at the 95 percent confidence level. When the four stations that came on-line for AFC equipment were not included i.e., Regent Centre, Wansbeck Road, Fawdon, and Bankfoot, the system MTF improved to 6,757, based on 567,612 transactions and 84 failures. The May MTF of 6,757 represented a 4.7 percent decline in system performance from April.

Table 6-5 presents the distribution of May vendor failures by affected subsystem and Table 6-6 presents the failures by type. As shown in Table 6-5, 45 (or 41 percent) of the 110 failures occurred in the magnetic ticket issuer/reader subsystem. Of these, 28 (or 62 percent) were the result of sensors not changing state, 13 were failures of the new strip feed contact, and four were failure to verify problems. Failures of the sensors were the largest individual failure type in May, representing nearly 26 percent of all failures recorded.

Thirty three (or 30 percent) of the total 110 failures occurred in the coin recycling subsystem. Thirteen of the 110 affected the coin selector. Twelve of these were coin jams in the selector slot. These represented nearly 11 percent of failures recorded for all vendors in the Metro system.

When the failures for the stations that came on-line in May were excluded, the failure distribution shown in Table 6-7 resulted. As can be seen from the table, the hierarchy of failures by subsystem affected is basically the same as those

TABLE 6-5 DISTRIBUTION OF TYNE AND WEAR MAY 1981 FAILURES BY SUBSYSTEM AFFECTED (ALL STATIONS)

SUBSYSTEM	NUMBER OF FAILURES	PERCENT OF TOTAL
Magnetic ticket issuer/reader	45	40.9
Coin recycling subsystem	33	30.0
Coin selector	13	11.8
Vault	9	8.2
Clock	3	2.7
Logic/PC Boards	3	2.7
Miscellaneous	4	3.6
TOTAL	110	99.9*

*Rounding error.

TABLE 6-6 DISTRIBUTION OF TYNE AND WEAR MAY 1981 VENDOR FAILURES BY TYPE (ALL STATIONS)

FAILURE TYPE	NUMBER	PERCENT OF TOTAL
Sensors in ticket transport do not change state	28	25.5
Fault in new strip feed contact	13	11.8
Failure to verify (encoding failure)	4	3.6
Cassette coin counter exceeds its capacity	1	0.9
Coin given in change and those viewed by cassette exit cells do not tally	2	1.8
Coin in cassette not identical to coin viewed by selector	3	2.7
Coin in cassette not viewed as correct by selector	3	2.7
Coin viewed by selector but not viewed by cassette	4	3.6
Cassette entry cell still blocked	2	1.8
Cassette Cam not at rest after a rotation command	6	5.5
Coin sent to vault when cassette not full	2	1.8
Cassette full but coin not sent to vault	4	3.6
Cell on cassette exit towards vault; vault still blocked	1	0.9
Cell on cassette exit towards return cup still blocked	4	3.6
Coin jammed in cassette	1	0.9
Coin selector exit cell blocked	1	0.9
Selector slot jammed or sticking	12	10.9
Missing vault	7	6.4
Unauthorized unlocking of vault or coin recycler	1	0.9
Vault Frame	1	0.9
Incorrect time on clock	3	2.7
Fare selection board replaced	3	2.7
Fare selection panel replaced	2	1.8
Escrow box	1	0.9
No cassette ticket issued on command	1	0.9
TOTAL	110	99.7*

*Rounding error

TABLE 6-7 DISTRIBUTION OF TYNE AND WEAR MAY 1981 VENDOR FAILURES BY AFFECTED SUBSYSTEM (EXCLUDING FOUR NEW STATIONS)

SUBSYSTEM	NUMBER OF FAILURES	PERCENT OF TOTAL
Magnetic ticket issuer/reader	41	48.8
Coin recycling subsystem	19	22.6
Coin selector	10	11.9
Vault	8	9.5
Clock	2	2.4
Logic/PC Boards	1	1.2
Miscellaneous	3	3.6
TOTAL	84	100.0

shown in Tables 6-3 and 6-5. Approximately 49 percent of the failures affected the magnetic ticket issuer/reader subsystem. Twenty three percent affected the coin recycling subsystem, 12 percent were related to the coin selector and 10 percent were related to the vaults.

In May, Monkseaton, Benton and Wansbeck Road had MTF rates significantly below the system average at the 95 percent confidence level. The rates were 2,213, 1,876 and 1,756 respectively (Table 5-8 above). Of the 16 failures that occurred at Monkseaton, four were failures in the new strip contact. Three of these occurred at vendor #11. Thirteen of these failures were recorded system-wide in May. Four other Monkseaton vendor failures were missing vaults (all at vendor #7). Note that seven of these failures occurred system-wide. Monkseaton also experienced two coin cassette failures that were the result of the cassette exit cell to the return cup being blocked. Four of these failures occurred system-wide. The individual machine MTF rates for this station in May were 3,787 (#2), 2,936 (#6), 1,942 (#11) and 1,276 (#7). The reliability for vendor #7, which experienced five failures, was found to be significantly below the system total at the 95 percent confidence level.

For Benton in May, four of the eight failures were sensors in the ticket transport that did not change state. Three of these occurred at vendor #43. In fact, six of the eight Benton May failures occurred at vendor #43 which had an MTF rate of 1,178. The other individual vendor MTF rates were 4,625/0 (#45), 2,640 (#34), and 679 (#35). Only vendor #43 had a May MTF rate significantly below the system average at the 95 percent confidence level. Of its six failures, three were sensor-related as stated above, two occurred in the coin recycling subsystem and one was a missing vault.

At Wansbeck Road, four of the eight May failures occurred in the coin recycling subsystem and two failures were jammed coin selector slots. Two of the recycling subsystem failures were the result of full coin cassettes not sending a coin to the vault (vendor #64). Four of these failures occurred throughout the Tyne and Wear Metro system in May 1981. Individual vendor MTF rates were 3,456 (#63), 1,169 (#64), 856 (#61) and 437/0 (#62). The reliability for vendor #64 was found to be significantly below the system total at the 95 percent confidence level. Three of the five failures for this vendor occurred in the coin recycling subsystem.

When the performance data for April and May for the Tyne and Wear vendors were combined, and the data for the new stations excluded, the system MTF was 6,908, based on over one million tickets vended and 155 failures. Table 6-8 presents the combined failure distribution by subsystem affected. As shown in Table 6-8, and as can be expected from a review of previous tables, failures occurring in Tyne and Wear vendors for the two month period affected major subsystems in the following hierarchy: magnetic ticket issuer/reader (48 percent), coin recycling subsystem (25 percent), coin selector (10 percent), logic (3 percent). The majority of the ticket issuer/reader failures was failure of sensors to change state (63 percent), and failures related to the new strip feed contact (25 percent). Most of the coin selector failures were selectors being jammed or stuck.

When the data were combined, four stations were found to have MTF rates significantly below the system total at the 95 percent confidence interval. The stations were Whitley Bay, Monkseaton, Benton and Cullercoats (Table 5-9 above).

Whitley Bay experienced 25 failures over 105,488 tickets vended or an MTF rate of 4,220. The MTF was significantly below the system total due to the performance of the vendors in

TABLE 6-8 DISTRIBUTION OF APRIL AND MAY TYNE AND WEAR VENDOR FAILURES BY AFFECTED SUBSYSTEM (EXCLUDING FOUR NEW STATIONS)

SUBSYSTEM	NUMBER OF FAILURES	PERCENT OF TOTAL
Magnetic ticket issuer/reader	75	48.4
Coin recycling subsystem	39	25.2
Coin selector	16	10.3
Vault	13	8.3
Clock	4	2.6
Logic/PC Boards	4	2.6
Miscellaneous	4	2.6
TOTAL	155	100.0

April when 16 of 25 failures occurred. As discussed above, the performance of vendor #21 greatly influenced the overall station performance. Of the nine May failures, five were sensors not changing state, two were related to the coin recycling subsystem, one was a failure in the new strip feed contact, and one was a failure in the escrow box. The individual vendor MTF rates for the two month period were: 15,671 (#12), 8,028 (#1), 6,350 (#58), 1,726 (#4) and 338 (#21). Only vendor #21 had a reliability significantly below the system total at the 95 percent confidence level. However, it is significant to note that this is due to the performance of the machine in April. In May, the vendor had only two failures compared to eight in April. In addition, the machine vended 40 percent more tickets in May.

For Monkseaton, the MTF rate for each month was below the system total. However, the combined April-May MTF rate of 3,130 was significantly below the system average at the 95 percent confidence level primarily due to the performance of the vendors in May when 16 of the total 22 failures occurred. The increase resulted from more failures in the new strip feed contact (four in May versus one in April) and more instances of missing vaults (again, four versus one, all four at vendor #7). Individual vendor MTF rates were: 3,834 (#6), 3,691 (#2), 3,153 (#11) and 2,029 (#7). The reliability of vendor #7 was found to be significantly below the system total of 6,908 at the 95 percent confidence level.

Benton vendors had a combined MTF rate of 2,989. Eight of the eleven failures recorded occurred in May. Four of the eight were failures due to sensors in the ticket transport not changing states. No failures of this type occurred at Benton vendors in April. As discussed above, six of the eight May failures occurred at vendor #43. Individual MTF rates for the two months were: 8,906/0 (#45), 2,590 (#35), 2,397 (#34), and 2,074 (#43). The reliability of vendor #43 was found to be

significantly below the system total at the 95 percent confidence level.

At Cullercoats, the combined MTF was 3,480. In each month, this station had an MTF rate below the system total. Statistical tests indicate that the rates were not significantly below the system totals. However, when the two months were combined, the Cullercoats MTF was found to be significantly below the system total of 6,908.

Of the 12 failures recorded, five occurred in April and seven in May. Of the April failures, two were missing vaults, one was a failure in the coin recycling subsystem, one was a jammed coin selector slot, and the fifth was a failure in the fare selection PC board. In May, there were four failures in the coin recycling subsystem, two jammed selector slots, a missing vault, and a failure in the new strip feed contact. All three jammed selector slots occurred at vendor #51. Individual vendor MTF rates were: 7,031/0 (#50), 4,371 (#32), 2,410 (#60), and 2,391 (#51). None of the vendors had reliabilities significantly below the system total at the 95 percent confidence level.

6.1.3 Tyne and Wear Summary

Although system-wide vendor performance decreased from April to May, the difference was not found to be statistically significant. Vendor failures for both April and May were distributed similarly. When the data were combined, the hierarchy of failures by major subsystem affected was: magnetic ticket issue/reader (48 percent), coin recycling subsystem (25 percent), coin selector (10 percent) and logic (three percent). A further examination revealed that the majority of the magnetic issuer/reader failures were sensors not changing state, and failures in the new strip feed

contact. The recycling subsystem failures were distributed among nine subcategories. The coin selector failures were mostly jammed selectors. Logic failures were not detailed as to the cause of the failure. In one case, however, a CPU was replaced.

Individual stations found to have reliabilities significantly below the system total were examined and discussed. For these stations, reliabilities of individual vendors were examined as a means to identify equipment that was problematic. Table 6-9 presents a summary of the problem machines. Note that although Cullercoats had a station MTF significantly below the system total for the combined period, no machine was found to be significantly below the system total.

6.2 STUTTGARTER STRASSENBAHNEN

6.2.1 Analysis of Surveyed Equipment

On-Site Survey

Three failures were observed during the on-site survey of ten vendors at Hauptbahnhof station. All of the failures occurred at vendor #316. All resulted in a strip of six single-ride tickets being vended as one ticket. In each case, only the lead ticket of the strip contained data. An SSB technician was present each time. In two of the instances, the technician took about a minute to adjust the paper stock. In the third instance, the technician put the machine out of service. It was attended to 75 minutes later by a technician on the second shift. The repair time for this failure was 10 minutes. The maintenance report filed stated that a loose plug was tightened.

TABLE 6-9. SUMMARY OF RELIABILITIES FOR TYNE AND WEAR STATIONS AND THEIR VENDORS FOUND TO BE SIGNIFICANTLY BELOW SYSTEM TOTAL AT 95 PERCENT CONFIDENCE LEVEL

PERIOD	SYSTEM MTF	STATION	STATION MTF	VENDOR ID	VENDOR MTF	FAILURES/COMMENTS
Apr	7,087	Whitley Bay	3,046	21	236	Eight of 16 station failures; four - recycling subsystem, three - coin selector
May	5,882*	Monkseaton	2,213	7	1,276	Five of 16 station failures; four - missing vaults
		Benton	1,876	43	679	Six of eight station failures; three - magnetic ticket issuer/reader, two - recycling subsystem
		Wansbeck Road	1,756	64	1,169	Five of eight failures; three - recycling subsystems
Apr-May	6,908**	Whitley Bay	4,220	21	338	See April comment. Note that #21 improved its performance in May.
		Monkseaton	3,130	7	2,029	See May comment.
		Benton	2,989	43	2,074	See May comment.
		Cullercoats	3,480	N.A.	N.A.	No vendors found to be significantly below system total. Five failures in April, seven in May.

*Includes all stations.
**Excludes four new stations.
N.A. = Not Applicable.

Full Survey Week

It was determined that the paper and the plug were not the entire problem, because the situation occurred again. This time the printer was replaced and the problem was resolved. The repair time was 10 minutes. Two other failures occurred at the surveyed vendors during the week of July 27-31, but not during survey periods. Machine #109 developed a defective cable that was replaced in 10 minutes. In addition, machine #110 had a 1DM coin jammed in the recycling disc. Removal of the coin and checking of the machine took 15 minutes. If the adjustments to the paper stock are not considered, the total repair time for the four failures was 45 minutes or an average of approximately 11 minutes per failure.

The MTF for the sample of ten vendors for the entire survey week was 2,711 based on 16,265 tickets vended and six failures. Individual vendor MTF rates for those machines which exprienced failures were: 1,726 (#110), 1,344 (#109), and 270 (#316). The latter MTF was found to be significantly below the sample average at the 95 percent confidence level.

6.2.2 Analysis of Performance Measures Based on Property-Supplied Data

Selected Vendors - 6 Months Reliability Measures

As presented in Section 5, 6-month reliability measures based on maintenance records were computed for all 16 vendors inside the Hauptbahnhof and 6 vendors located outdoors - two outside Hauptbahnhof and four at Mohringen Bahnhof. The data are from January to June 1981. For the vendors inside the Hauptbahnhof, the sample average MTF was 21,214 with 47 failures, while for the six vendors located outdoors, the

MTF rate was 14,593 with 12 failures. The difference in performance was not found to be significant at the 95 percent confidence level.

Tables 6-10 and 6-11 present the distribution of failures for the indoor and outdoor vendors, respectively. Note that indoor machines vended more than five times the number of tickets than outdoor machines. For the indoor vendors, printer failures represented about 45 percent of all failures. Failures occurring in the coin guiding plate represented about 15 percent, followed by failures in the coin discs of the recycling subsystem (11 percent).

For the outdoor vendors, printer failures also represented the greater percentage of total failures (6 of 12). Failures in the coin guiding plate represented 25 percent, while no failures occurred in the coin discs. It should be noted that SSB eventually modified the material and design of the coin guiding plate. (See Appendix E).

The MTF rate for the printer subsystem for the indoor machines was 47,479. For the outdoor machines, the MTF rate was 29,186, which was 39 percent less. The difference was not found to be statistically significant.

Monthly SSB Vendor System Reliability - 1980

Monthly system reliabilities for SSB vendors in 1980 were presented in Table 5-16. The reliabilities were based on technical failures only, since failure data were unavailable in other categories. The system reliability for 1980 was an MTF of 14,042 with 1,107 failures. The months of June and August had MTF rates of 10,670 and 10,407, respectively, both significantly below the system total for the full year. The 105 technical failures in June were 14 percent greater than the monthly 1980 average of 92, while tickets vended in June were

TABLE 6-10. DISTRIBUTION OF SSB 1981 VENDOR TECHNICAL FAILURES BY COMPONENT AFFECTED - SELECTED INDOOR VENDORS

COMPONENT	NUMBER	PERCENT OF TOTAL
Coin Selector	2	4.3
Coin Guiding Plate	7	14.9
Coin Disc	5	10.6
Printer	21	44.7
Price Indicator	1	2.1
Cable/Electric	4	8.5
Miscellaneous	5	10.6
No Explanation	2	4.3
TOTAL	47	100.0

TABLE 6-11. DISTRIBUTION OF SSB 1981 VENDOR TECHNICAL FAILURES BY COMPONENT AFFECTED - SELECTED OUTDOOR VENDORS

COMPONENT	NUMBER	PERCENT OF TOTAL
Coin Selector	1	8.3
Coin Guiding Plate	3	25.0
Printer	6	50.0
Electrical	1	8.3
Miscellaneous	1	8.3
TOTAL	12	100.0

five percent less than the system monthly average. August displayed a similar pattern. The 110 August failures were 19 percent greater than the average, while tickets vended were 12 percent less than average. Since technical data for 1980 were not available by subsystem affected, further analysis of the failure data was not possible.

Monthly SSB Vendor System Reliabilities - 1981

Reliability measures for the SSB system in the first six months of 1981 were presented in Tables 5-17 through 5-21. The failure data were available in the five categories described in Section 5: technical, administrative, vandal, wrong information, and "other". In addition, technical data were further broken down by the subsystem/component that experienced the failure.

Table 6-12 presents the number of failures by category for each month and Table 6-13 presents the percentage of total monthly failures that each figure represents. Of the 2,218 failures recorded in the SSB system, 759 (or 34 percent) were in the "other" category, 577 (26 percent) were technical, 449 (20 percent) were due to vandals, 422 (19 percent) were wrong information, i.e., failures reported but no defect found, and less than one percent were administrative failures (e.g., out of tickets).

Table 5-17 indicated that the system reliability for SSB vendors over the six-month period was 3,311, based on all failures. The only month with an MTF significantly below this rate was January (2,519). Although fewer tickets were sold in January than in any other month, more failures occurred in January than in any other month (Table 6-12). The total of 451 failures was 22 percent above the six-month average of 370, 28 percent greater than the February-June average of 353 total failures, and 20 percent of the total 2,218 failures that

TABLE 6-12. MONTHLY DISTRIBUTION OF 1981 SSB VENDOR FAILURES BY CATEGORY

FAILURE CATEGORY	NUMBER OF FAILURES							MONTHLY AVERAGE
	JAN	FEB	MAR	APR	MAY	JUN	TOTAL	
Technical	84	83	98	99	126	87	577	96
Administrative	3	1	3	2	0	2	11	2
Vandal	125	63	72	71	60	58	449	75
Wrong Information	83	78	56	68	77	60	422	70
Other	156	115	133	110	132	113	759	127
TOTAL	451	340	362	350	395	320	2,218	370

TABLE 6-13. MONTHLY DISTRIBUTION OF 1981 SSB VENDOR FAILURES BY CATEGORY (PERCENT)

FAILURE CATEGORY	PERCENT OF FAILURES FOR THE MONTH						MONTHLY AVERAGE
	JAN	FEB	MAR	APR	MAY	JUN	
Technical	18.6	24.4	27.1	28.3	31.9	27.2	26.0
Administrative	0.7	0.3	0.8	0.6	0.0	0.6	0.5
Vandal	27.7	18.6	19.9	20.3	15.2	18.1	20.2
Wrong Information	18.4	22.9	15.5	19.4	19.5	18.8	19.0
Other	34.6	33.8	36.7	31.4	33.4	35.3	34.3
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0

occurred in the six-month period. Tickets vended in January represented slightly above 15 percent of the six-month total.

A further examination of January failures reveals that figures for the month were the highest in three failure categories: vandal failures, wrong information failures, and "other" failures. The 125 vandal-related failures represented 28 percent of the 449 that occurred in the six-month period. In addition, the number of vandal failures in January was 67 percent above the six-month average of 75, and 92 percent above the February-June average of 65.

In the wrong information category, the 83 January failures represented 20 percent of the total 422 failures recorded in this category. It was 19 percent above the six-month average of 70 and 22 percent above the February-June average of 68.

In the "other" failure category, the total of 156 January failures was 21 percent of the total 759 failures. The January figure was 23 percent greater than the six-month average of 127 and 54 percent greater than the February-June average of 101. A further examination of this category indicates that the greatest number of failures occurred in the sub-category comprised of failures in the return cup, foreign object channel and information panel. The 56 failures in this sub-category represented 36 percent of the 156 total "other" failures. In addition, the 56 failures were 60 percent greater than the subcategory six-month average of 35, and 81 percent greater than the February-June average of 31.

When the vandal-related failures and administrative failures were not included in the computation of reliabilities, the system MTF was 4,178 (Table 5-19). Two months, January (3,518), and May (3,765), had MTF rates significantly below the system total.

For January, the 323 failures experienced in the three categories utilized - technical, wrong information and "other" - represented 18 percent of the total 1,758 failures that occurred throughout the SSB system for the six-month period. Since the 84 technical failures were less than the monthly average of 96, the January reliability figure can be explained along the same lines as its overall MTF rate. It was a month in which the highest number of failures occurred in the wrong information and "other" categories, and in which the lowest number of tickets were sold.

The 335 failures for May were the largest monthly sum of the three failure categories. The May total represented 19 percent of all failures in these categories. May ticket sales represented 17 percent of all tickets sold. May, however, experienced the largest number of technical failures. The 126 failures recorded in this category represented 22 percent of the total 577 technical failures for the six-month period. The May figure was 31 percent greater than the six-month average of 96 and 40 percent greater than the 90 technical failures averaged for the other five months.

In addition to the technical failures, SSB vendors experienced 132 "other" failures in May. This was the third largest figure for this category which averaged 127 failures per month.

Table 5-20 presented the SSB monthly system reliability based on technical failures and four of the six subcategories of "other" failures. As discussed in Section 5.4.1 above, the subcategories, service voltage, plugs and cable, service indicator, and return cup were included, while the subcategories, cleaning after failure, and deformed coins were excluded. The system six-month MTF was 6,948. January displayed an MTF rate of 5,738, significantly below the system total. Although the reliability measure for May was the second

lowest at 6,181, and the number of May failures the greatest (204), the reliability measure was not found to be significantly below the system total at the 95 percent confidence level.

Since January experienced 84 technical failures compared to the six-month average of 96, the comparatively low reliability in January was due to the 114 failures in the four "other" subcategories. This number was 24 percent of the total 480 failures for the six-month period, 43 percent greater than the six-month average of 80, and 56 percent greater than the February to June average of 73 failures.

When the reliability measures were generated based only on technical failures, May, with an MTF of 10,010, was the only month with a reliability significantly below the system total of 12,728. As mentioned above, this was due to the large number of technical failures. A further analysis of the technical failures was based on Table 6-14, which presents the breakdown of SSB technical failures by subsystem or component affected. In May, there were 20 coin acceptor failures; the six-month average was nine. In addition, vendors in the SSB system experienced 48 printer failures compared to the monthly average of 38. The number of failures for both the acceptor and the printer were the highest monthly figures for each.

Table 6-14 also indicates that of the 577 technical failures recorded, 226 (39 percent) were related to the printer, 16 percent occurred in the coin guiding plate, 14 percent occurred in the coin discs and nine percent in the coin acceptor. Combining the failures related to the logic subsystem resulted in 37 failures, roughly six percent of the total.

TABLE 6-14. MONTHLY DISTRIBUTION OF SSB 1981 VENDOR TECHNICAL FAILURES BY SUBSYSTEM AND COMPONENT AFFECTED

SUBSYSTEM OR COMPONENT	MONTH (1981)							PERCENT OF ALL TECH. FAILURES
	JAN	FEB	MAR	APR	MAY	JUN	TOTAL	
Coin Acceptor	7	5	5	10	20	6	53	9.2
Control Device for Discs	1	1	-	1	2	1	6	1.0
Coin Guiding Plate	17	17	22	11	12	13	92	15.9
Reserve Coin Drum	3	-	-	-	3	-	6	1.0
Coin Discs	9	11	10	15	15	18	78	13.5
Logic Rack	-	-	-	3	-	1	4	0.7
Div PC Board	5	2	1	1	2	2	13	2.3
DSP PC Board	-	2	1	2	4	1	10	1.7
CPU PC Board	-	1	2	2	4	1	10	1.7
Power	4	3	6	2	-	-	15	2.6
Push-Button Plate	-	-	1	-	1	-	2	0.3
Push-Button Interface	1	-	-	2	1	1	5	0.9
Price Indicator	3	2	2	-	2	2	11	1.9
Printer	28	32	42	41	48	35	226	39.2
Remote Control	-	-	-	-	1	-	1	0.2
Heater	-	-	2	-	-	-	2	0.3
Wrong Number of Failure Indication	6	7	4	9	11	6	43	7.5
TOTAL	84	83	98	99	126	87	577	100.0

6.2.3 SSB Summary

Failures for the ten vendors observed during the on-site survey were limited to three, all occurring at the same machine. Each was the result of the same problem which was remedied when the printer was removed. When the maintenance reports for the full survey week were examined, two more failures were found to occur at the surveyed vendors. One was a coin jammed in a recycling disc, the other was a defective cable.

The performance of indoor vendors over a six-month period was 45 percent better than six outdoor vendors. The six-month period covered the winter and spring, 1981. However, the differences in performance were not found to be statistically significant. Distributions of failures for each group were similar except for the absence of coin disc failures in the outdoor machines. For each group, printer failures represented about half of all failures with coin guiding plate failures second.

An examination of the system-wide monthly performance of SSB vendors was presented. The performance measures were based on failures broken down into several failure categories. Failures for months that displayed performance measures significantly different from the system total were examined in an effort to explain the differences. In addition, technical failures for the first six-months of 1981 were presented by subsystem or component affected. The hierarchy of technical failures as can be determined from Table 6-14 was printer (39 percent), coin guiding plate (16 percent), coin recycling discs (14 percent), coin acceptor (nine percent) and logic (six percent). The SSB recently modified the material and design of the coin guiding plate.

6.3 REGIE AUTONOME DES TRANSPORTS PARISIENS

As discussed above, reliability measures for RATP gates and vendors were not generated for lack of transaction data. This section presents a discussion of the failures and occurrences observed by IOCS surveyors.

The failures observed included two hard failures for gates and several ticket jams. Failures did not occur at the vendors during the on-site survey, but two vendors, #30880 and #V1 at Chatalet les Halles, experienced failures during non-survey times that resulted in 50 percent availability during the survey period. The nature of the problems was not available from RATP officials.

Several occurrences were observed for the vendors during the survey period. Both the in-service and experimental vendors were observed rejecting coins. In some cases, the coins were then accepted by another machine. Also, the majority of the vendors that were in-service for the entire survey period were in the exact-change-only mode half the time.

The hard failure that occurred at the CAMP/CGA gates required the removal of the tripod barrier and several associated components. As presented in Section 5.5.3, diagnosis and replacement were performed by two technicians. Active repair time was one hour. The hard failure that occurred at the RER gates was a failure in a PCB of the central logic system. The technician diagnosed the problem, obtained the necessary part, and installed the new board. Active repair time was 40 minutes.

The most common problem observed with both the RATP Metro and RER gates was the intermittent acceptance of tickets. Many patrons were not able to insert their valid tickets into the

gates and had to move to another gate that would accept the ticket. In most cases, other patrons, particularly those with Orange Cards, were able to use the problem gate. In one case the gate was freewheeled. In another, a technician arrived and cleared the jam in about a minute.

6.4 COMPARISON WITH AFC EQUIPMENT USED AT U.S. PROPERTIES

The performance of the AFC equipment at Tyne and Wear and Stuttgarter Strassenbahnen can be compared to the performance of similar equipment at U.S. transit properties. Specifically, the performance of the vendors and gates at Port Authority Transit Corporation (PATCO) of Camden, New Jersey, Washington Metropolitan Area Transit Authority (WMATA), and the Illinois Central Gulf (ICG) commuter line in Chicago, Illinois, were compared. In addition, the performance of coin and ticket-accepting gates at Metropolitan Atlanta Rapid Transit Authority (MARTA) was also compared. The ICG and PATCO AFC systems are considered first-generation American equipment, while the WMATA and MARTA AFC systems are considered second-generation systems. All the American systems use farecards of the credit-card size. (Note that at American properties, tickets are referred to as farecards.)

The PATCO High-speed line began operations in 1969 on a 14.5-mile line between downtown Philadelphia, Pennsylvania and Lindenwald, New Jersey. The PATCO line comprises 13 stations, which were designed for unmanned operation. Rolling stock consists of 121 transit cars. PATCO transported 11.3 million passengers in 1980.

The PATCO AFC system is comprised of self-service farecard vendors, automatic gates, transfer dispensers, and dollar bill changers. The vendors were designed by Advanced Data Systems and placed in operation in 1969. The vendors dispense one- and

two-ride tickets that correspond to established zone fares. The tickets are magnetically encoded and used for entry and exit at stations within each zone. PATCO has about 61 vendors in-service, all equipped with bill verifiers and coin acceptors. Some vendors provide change.

The 75 gates utilized by PATCO were designed by Cubic Western Data (CWD) and placed in operation in 1975. Upon entry into the system, the patron must insert the farecard in a specified way, i.e., only a single orientation is accepted. This is true for all three American properties. The entry gates read the encoded farecard, deduct a trip, and rewrite the farecard for the appropriate number of remaining rides. The exit gates read the farecards and return or capture them as appropriate.

The ICG commuter line is an electrified railroad with approximately 31 miles of mainline and nine miles of branch lines operating between Chicago, Illinois and its southern suburbs. The ICG line is comprised of 49 stations, designed for unmanned operation. Since October 1974, there has been full automation of stations using self-service ticket vendors, automatic gates, passenger assistance telephones, a two-way intercom speaker system, a platform public address system, and a closed circuit television system. In addition, station agents are used during the evening peak period at two downtown stations.

The ICG AFC system is comprised of 112 ticket vendors and 169 entry/exit automatic gates. Each piece of AFC equipment is connected to a central monitoring facility, which automatically records when equipment goes out of service. The vendors and the gates were designed by CWD, and placed in service between 1973 and 1976. The vendors dispense magnetically encoded one-way, round-trip, and weekly farecards (seven round-trips). In addition, they incorporate bill verifiers and coin

acceptors, and dispense change. Fares are based on travel between established zones. The gates are utilized by ICG for both entrance and exit control, similar to the PATCO equipment.

The WMATA rail system, which serves downtown Washington, D.C. and its near suburbs, began operation in June 1977. The line is 40 miles in length, with 30 miles currently under construction. The system is comprised of 38 stations and was designed for unmanned station operation. However, WMATA currently uses agents at busy stations to enhance throughput. The fare structure is based on length of trip and time of use (peak versus off-peak). Rolling stock consists of 298 transit cars. The WMATA rail system transports almost 300,000 riders per day.

The WMATA AFC system is composed of self-service ticket vendors, entry and exit gates, add-fare machines, and a Data Acquisition and Display System that monitors and controls the AFC equipment at each station. The equipment was designed and manufactured by CWD. The vendors dispense farecards of any chosen value from $0.45 to $20.00 for cash or cash plus the trade-in value of a used farecard. The vendors accept both coins and bills and dispense change. The gates in the WMATA AFC system consist of entry, exit, and reversible gates. The gates read, write and verify farecard information. Exit gates also print the value remaining on the farecards and capture them when their value is used up.

The MARTA rail system, which serves Atlanta, Georgia and surrounding communities in Fulton and Dekalb counties, was opened in June 1979. The system is currently operating an 11.8-mile East-West line and a recently-opened (December 1981) 1.9-mile portion of a proposed 23.4-mile North-South line. The full system will cover 53 route-miles, comprise two main lines, three branches, and 40 stations. Stations were designed for unmanned operation, although agents currently work at the

busiest stations during peak hours. Rolling stock consists of 120 transit cars. The system utilizes a flat fare structure, with lower fares available during off-peak hours for senior citizens and handicapped persons. Weekly and monthly passes are available. Free transfers are available for connection with buses, and transfers from buses allow free entrance to the rail system, which transports about 68,000 people per day.

The MARTA AFC system is comprised of 128 automatic gates manufactured by Cubic Western Data. A typical set of gates at a MARTA mezzanine consists of one fully accessible gate, three entry gates, one exit-only gate and a "dummy" console (stanchion). The gates incorporate microprocessor technology. The entry and exit gates utilize a tripod barrier and the fully accessible gates have a hinged service-type barrier. The entry gates accept both coins and magnetically encoded farecards. The entry gates read, write and verify farecard information. Some farecards (namely, bus-to-rail transfers) are captured. In addition, the gates dispense transfers from paper roll stock. Under a modification program, MARTA has been experimenting with fanfold transfers.

Comparison of Vendor and Gate Reliabilities

Comparisons of performance measures were made on the basis of the type of data used to generate the measures. Reliability figures based on data collected during on-site surveys were analyzed separately from those based on maintenance or failure records provided by the properties. Failures that were related to bill acceptors were not included in the assessment since the European machines do not incorporate the devices.

On-site data for each property except PATCO were provided by a one- or two-week survey conducted by IOCS observers. The reliability of the WMATA equipment was based on both on-site data collected by the property and on-site data collected by

IOCS observers. The property collected approximately eight months of peak hour data between October 1978 and August 1979. Surveys were conducted two days a month during the peak periods. Data were also collected in February, March and April 1980 by IOCS and Automated Services Incorporated to assess the performance of two retrofit programs undertaken by the property. The data collection methodologies for both the WMATA and IOCS surveys were quite similar. In the tables that follow, the retrofit programs are referred to as Retrofits A and B. Retrofit A involved changes to various components of the ticket transport, designed to decrease the incidence of farecard jame. Retrofit B included changes to the coin acceptor and ticket transport.

The property-supplied PATCO data covered a two-week period commencing October 27, 1980. Both the ICG on-site and property-supplied data covered the two-week period beginning February 16, 1981. The MARTA data were for the two-week period commencing October 26, 1981.

Vendors

Table 6-15 presents the comparative reliability figures for ticket vendors based on the on-site surveys. The reliabilities of the vendors at the American properties were compared statistically to both European properties. The reliabilities of the vendors at the American properties were found to be significantly less than those of the vendors at each of the European properties at the 95 percent confidence level.

An analysis of the performance differences based on failure data was not possible due to the low number of failures that occurred in the European machines. Nevertheless, the breakdowns of vendor failures at ICG and WMATA are presented. Note that the WMATA failure classifications are general, since, in many cases, specific details as to subsystem affected and

TABLE 6-15. COMPARISON OF EUROPEAN AND AMERICAN VENDOR RELIABILITIES BASED ON ON-SITE DATA

PROPERTY	NO. OF VENDORS	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
Tyne & Wear	19	.999789	4,708	14,123	3
SSB	10	.999451	1,821	5,464	3
ICG	9	.996613	295	5,019	17
WMATA (Pre-Retrofit)	40	.993759	160	153,983	961
WMATA (Retrofit A)	14	.994282	175	20,638	118
WMATA (Retrofit B)	6	.997630	422	20,673	49

TABLE 6-16. COMPARISON OF EUROPEAN AND AMERICAN VENDOR RELIABILITIES BASED ON PROPERTY-SUPPLIED DATA

PROPERTY	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
Tyne & Wear	.999855	6,908	1,070,781	155
SSB	.999761	4,178	7,344,284	1,758
PATCO	.999846	317	97,960	309
ICG	.992074	126	10,976	87

the nature of problem were not available. Of the failures that occurred at the ICG vendors, seven (41 percent) were farecard jams, eight (47 percent) were jams in the change dispenser, and two were failures reported but no defect found. The WMATA pre-retrofit failures were broken down as follows: 43 percent farecard jams, 24 percent coin jams, 13 percent other soft failures and 19 percent hard failures. For Retrofit A, the failure distribution was 31 percent each for farecard jams, coin jams and other soft failures, and seven percent hard failures. For Retrofit B, the distribution was 51 percent coin jams, 13 percent farecard jams, 30 percent other soft failures, and six percent hard failures.

Table 6-16 presents the vendor reliabilities based on maintenance records and failure counts provided by the properties. For each property, with the exception of ICG, the figures represent system-wide measures. The ICG figures are for about one-third of the vendors. The reliabilities of the vendors at the American properties were found to be significantly less than the reliabilities of the equipment at the European properties. However, due to differences in failure reporting and classification, these observations should be viewed with caution.

This caution also applies to an assessment of the failure distributions shown in Table 6-17. Given the failure diagnostic feature of the European vendors, assignment of failures to specific subsystems is more accurate than for the vendors at the American properties. For the latter, many of the failures could not be specifically assigned to subsystems, resulting in large percentages for the "other" failure category, as shown in Table 6-17. Note that this category is not the same as that used previously for SSB.

Despite the limitations of the data, the general pattern of failures can be discerned for the American properties. PATCO

TABLE 6-17. COMPARISON OF EUROPEAN AND AMERICAN VENDOR FAILURES BY SUBSYSTEM AFFECTED (PERCENT) - PROPERTY-SUPPLIED DATA

	T&W	SSB	ICG	PATCO
Ticket Issuer	48.8	39.2	25.6	49.8
Coin Recycling	22.6	29.4	N/A	N/A
Change Dispenser	N/A	N/A	27.8	N/D
Coin Acceptor	11.9	9.2	7.8	19.7
Logic	1.2	6.4	1.1	N/D
Other (Includes both Soft and Hard)	15.5	15.8	37.7	30.5

N/A = Not applicable.
N/D = No data.

TABLE 6-18. COMPARISON OF EUROPEAN AND AMERICAN GATE RELIABILITIES BASED ON ON-SITE DATA

PROPERTY	NUMBER OF GATES	RELIABILITY R	MTF	SAMPLE SIZE (TRANSACTIONS)	FAILURES
Tyne & Wear	16	.999903	10,299	20,597	2
ICG	28	.999781	4,570	86,842	19
WMATA (Pre-Retrofit	24	.998007	502	191,696	382
WMATA (Retrofit A)	18	.998592	712	134,268	189
WMATA (Retrofit B)	7	.999551	2,220	153,600	69
MARTA*	26	.999425	1,740	106,122	61
MARTA**	26	.999588	2,427	80,099	33

*Overall machine reliability.
**Reliability excluding coin acceptor transactions and failures

vendors had roughly the same percentage of ticket issuer failures, but a higher percentage of coin acceptor failures than the Tyne and Wear and SSB vendors. ICG had a lower percentage of ticket issuer and coin acceptor failures, but had the highest "other" percentage at roughly 38 percent. The percentage of change dispenser failures was similar to those for the coin recycling subsystems of the European vendors.

For PATCO and ICG, the ticket issuer failures were considered jams while jamming occurred less frequently in the European equipment. The difference is partially due to the lack of detail in the failure reports for the American equipment, since, in some cases, jams were assumed for lack of detail. However, the difference could also be due to the design of the equipment. For example, the ICG vendors rely on a spring-loaded ticket stacker that feeds tickets to the ticket issuer. In cases observed by IOCS surveyors, tickets would get stuck between the stacker and issuer. Problems of this nature are uncommon in the Tyne and Wear machines with its ticket stock being unrolled into the ticket issuer, or in the SSB vendors with its fanfolded stock being pulled into the printer subsystem by a sprocket feeder.

Of course, the newer equipment also has problems associated with it. In most cases for the Tyne and Wear equipment, the problems in the ticket issuer put the machine out-of-service after ticket delivery. For the SSB vendor, the vast majority of "ticket issuer" failures were printer failures.

Gates

Table 6-18 presents the comparative performance measures for automatic ticket-accepting gates based on data collected during on-site surveys. Although the reliability for the gates at ICG were lower than the Tyne and Wear gates, the difference was not found to be statistically significant.

The reliability of the Tyne and Wear gates was significantly greater than that of the MARTA gates. Note that the MARTA gates accept coins, tokens and tickets. However, even when the coin acceptor failures were not included in the reliability computation, the reliability of the Tyne and Wear gates was still significantly greater than that of the MARTA gates at the 95 percent confidence level.

The reliability of WMATA gates is also shown in Table 6-18. Pre-retrofit reliability for a sample of 24 gates was 502 MTF. Under the retrofit programs, reliabilities increased to 712 for Retrofit A and 2,220 for Retrofit B. The reliability of each WMATA sample was found to be significantly less than that of the Tyne and Wear sample at the 95 percent confidence interval.

Maintenance

This section presents summary descriptions of the maintenance organizations of the three European properties and two American properties, PATCO and ICG. In addition, the impact of maintenance on the performance differences between the European and American equipment is discussed.

At Tyne and Wear maintenance for both the vendors and the gates is provided by a subcontractor. As part of the original contract with Crouzet, Tyne and Wear was provided a one-year equipment warranty. Crouzet subcontracted Balfour-Kilpatrick Inc. to provide the maintenance/warranty service.

The AFC maintenance organization comprises six electronic technicians, two engineers, i.e., senior technicians, and a supervisor. Under a program initiated by Tyne and Wear, three of the technicians are Metro employees, who are being trained to repair equipment coming out of warranty.

Maintenance is divided into two levels. The first is on-site correction and routine preventive maintenance. The latter is carried out on gates and vendors about every six weeks, in accordance with an extensive checklist of items to be attended (see Appendix C). The second level consists of repairs and overhauls in the workshop.

When a gate or vendor goes out of service, a control center is automatically notified via a computerized Remote Control Indicator (RCI) system. The message sent to the center indicates whether the out-of-service condition is due to a technical failure, a full vault, or ticket stock. If due to a technical failure, a supervisor at the center informs a maintenance technician in the field by a two-way radio.

The technician can utilize failure diagnostics in the machines to determine the problem. When the repair is completed, the technician fills out an Intervention Sheet, a copy of which is kept in the machine while another is filed at the maintenance shop. When the machine is put back into service, it is indicated automatically on the RCI system. When they are not attending to on-site failures, Tyne and Wear AFC technicians are either doing preventive maintenance or repairing or overhauling AFC equipment in the workshop.

The SSB AFC maintenance organization comprises 25 technical and maintenance support personnel located at a central workshop. During the day, there is a team of two technicians in the field who are in radio contact with the central facility. Since the machines are not monitored electronically, patrons and drivers are relied upon for information on out-of-service vendors.

In the field, the technicians make necessary minor adjustments, e.g., clearing paper jams in the printer or removing bent coins. In addition, for preventive maintenance

and major repair, the technicians replace components and subsystems and bring them back to the central workshop where more highly skilled personnel attend to the equipment. Several of the major subsystems, such as the printer, coin acceptor, and coin recycler, are replaced and preventively maintained about once a year (see Appendix F). However, machines that experience extensive use usually have the printer replaced every six months.

After each minor repair or replacement, the field technician files a failure report that is kept at the central facility. In addition to these, permanent maintenance records for the machine as a whole and each major subsystem are kept on file by SSB.

At RATP, each rail system has its own AFC maintenance organization. The Metro has a centralized organization based around a main workshop, while RER has a decentralized organization comprised of small workshops located at various stations.

The Metro AFC maintenance organization consists of about 45 technicians and their supervisors. There are separate groups for preventive maintenance and equipment repair. These groups are futher subdivided by equipment type. Preventive maintenance is carried out on the gates about once every 4-5 weeks, and on the ADARs about once every 5-12 weeks, depending on ticket volume.

For major failures, i.e., those not able to be fixed by a station agent, a technician is contacted via two-way radio by a central dispatcher. Major repairs are, if possible, done on-site, with workshop technicians primarily used for overhaul of major components as part of the preventive maintenance program.

The RER AFC maintenance organization consists of about 40 technicians and their supervisors. The technicians each cover an assigned area of two to three stations. RER AFC technicians can do preventive maintenance and repair on all types of AFC equipment. When a failure occurs that a station agent cannot fix, the station master contacts the appropriate maintenance workshop.

Gates in the RER are preventively maintained once every 7-8 weeks. For vendors, the period is 3-12 weeks depending on ticket volume. The experimental vendors have been preventively maintained on a 6-8 week basis.

The PACTO AFC maintenance organization consists of ten people: a foreman, eight electronic technicians and one repair man. On weekdays during the daytime hours (including both morning and evening peak periods), there are two technicians in the field responding to calls for repair from an operator in a monitoring center. One technician covers the Pennsylvania side, the other the New Jersey side of the system. The operator receives patron complaints and information concerning AFC equipment problems and contacts the appropriate technician. The technicians do repair work only. When finished with a job, they call the operator to let it be known that the repair has been done, and to inquire about another job. In some cases, these technicians will find and repair unreported failures.

In addition to the field technicians, the foreman, two electronic technicians and the repair man work at a central shop facility. One of the technicians and the repair man do preventive maintenance and overhaul. The second technician does component repair, primarily on electronics and coin acceptors. At PATCO, vendors are not preventively maintained but are attended on a repair basis. Gates, on the other hand, are preventively maintained on a fixed schedule by component. For example, the ticket handler is maintained once per year.

The ICG AFC maintenance organization consists of 29 persons, two of whom are supervisors. This number includes a group of six field electronic technicians responsible for the upkeep of the PAL (Passenger Assistance Line) equipment. (The PAL is a central monitoring facility providing patron assistance, closed circuit television and public address system.) Another group of four electronic technicians work at the central workshop and do equipment rebuilding, redesign and modification under a research and development program.

The remaining personnel provide repair and preventive maintenance of vendors and gates, and are assigned into one of four coverage areas, each with its own small shop.

On weekdays during daytime hours (including both morning and evening peak periods), there are either one or two electronic technicians covering each area. These workers are contacted by PAL operators who inform them of equipment problems. After each repair, the technicians fill out Trouble Logs indicating the type of failure repaired. If not working on a repair, the technicians are preventively maintaining the equipment. (Gates and vendors are preventively maintained about once a week.) In rare instances where a bench is required, the technicians will bring a part back to a shop for repair.

At the central maintenance facility there are three electronic technicians assigned to do simple electrical and mechanical repairs. Sometimes these workers are dispatched to the field to handle additional workload.

Maintenance and Performance

The impact of maintenance on the performance differences between the European and American equipment was considered. The components of maintenance described above, i.e., policy,

organization and technique, certainly affect equipment performance. However, with respect to reliability, this effect is difficult to quantitatively assess because of several factors, such as the type, generation and mix of equipment in-service, and technician skill levels and workloads.

These considerations notwithstanding, a rough estimate of level of effort can be generated based on equipment per maintenance personnel measures. These have been generated for Tyne and Wear, SSB, PATCO and ICG, and are presented in Table 6-19 with corresponding reliability measures. (Note that the vendor MTFs are based on property data, the gate MTFs, with the exception of the PATCO figure, are based on on-site data. The PATCO gate reliability is shown for reference, and, in any case, would be higher than a reliability based on on-site data.)

As can be seen in Table 6-19, SSB and Tyne and Wear have higher equipment per maintenance personnel ratios, i.e., technicians and repairmen cover more machines, yet the reliabilities of the equipment were higher than both PATCO and ICG. (Significantly higher in the case of the vendors, not significantly higher for the gates.) However, it is not possible, based on such limited data and the cautions presented above, to infer with any statistical confidence the predominant reason(s) for this anomalous situation. In other words, it is just as likely that the significantly greater performance of the European equipment is due to equipment characteristics (state-of-the-art) than to maintenance level of effort, technique, organization or policy. Common sense suggests that a mix of the factors are responsible, but isolating any of these is not possible based on limited data.

TABLE 6-19. COMPARISON OF EUROPEAN AND AMERICAN AFC EQUIPMENT PERFORMANCE AND MAINTENANCE WORKLOADS

PROPERTY	VENDORS	VENDOR MTF*	NO. OF GATES	GATE MTF**	NO. OF AFC MAINTENANCE PERSONNEL	AFC EQUIPMENT/ WORKER
T&W	65	6,908	89	10,299	9	17.1
SSB	485	4,178	N/A	N/A	25	19.4
PATCO	61	317	75	5,907	10	13.6
ICG	112	126	169	4,570	19	14.8

*MTFs based on property data.
N/A = Not applicable.
**MTFs based on on-site data (except PATCO)

6.5 APPLICATION TO U.S. PROPERTIES

An attempt to determine the potential use of AFC equipment to a specific transit property is influenced by several factors. Chief among them is fare collection policy. Fare collection policies vary widely among properties from flat fare systems such as MARTA and Chicago Transit Authority, to simple zone systems such as ICG and PATCO, to trip length and time of use systems such as WMATA. These fare collection policies impact the type and mix of AFC equipment required.

Vendors can be configured to sell a variety of stored-ride or stored-value tickets. Vendors can be equipped with bill acceptors or used in conjunction with bill changers. The machines can be designed to provide change or accept only exact fare. Gates can be used for entrance-only, exit-only, or both entrance and exit control. Gates can include ticket transports and/or coin acceptors. If desired, gates can incorporate transfer dispensers.

This section identifies some of the advantages and disadvantages of the Tyne and Wear, RATP and SSB equipment. It also indicates ways that the equipment might apply to U.S. transit systems such as PATCO, ICG and WMATA.

The ticket vendors at Tyne and Wear are configured such that only individual single-ride reduced and full fare tickets are sold. Ticket prices are determined by the zones of trip origin and destination. The machines only accept coins but do have the capability to incorporate bill acceptors. In addition, the machines can be programmed to deliver a variety of ticket types. The Crouzet vendors currently being tested at the RATP Metro and RER deliver individual and carnets (groups of ten) of single-ride tickets for all zones, and weekly multi-ride tickets for an urban zone.

The Edmondson size ticket delivered by the Crouzet vendors has the advantage of being able to be inserted in a gate in any of four ways. This is due to the encoding on the ticket and the use of multiple read and write heads in the gates. The farecards used at the American properties are larger and must be inserted in a specific way. The more flexible Edmondson ticket can facilitate passenger flow, since patrons do not need to take time to orient the ticket in the proper way.

The SSB vendor provides reduced and full fare single- and multi-ride tickets based on a complex zone system. The single tickets are about the same size as the Tyne and Wear tickets (30 mm x 76 mm) while the multi-ride tickets are several times the single ticket size (60 mm x 120 mm). The tickets are not magnetically encoded since SSB does not use automatic gates but relies on an honor system enforced by roving inspectors. Manufacturer representatives have indicated that the printer subsystem could incorporate a magnetic encoder. In addition, the machines, which only accept coins, could be equipped with a bill acceptor. Similar equipment in-service in Stuttgart and Munich, not of the same manufacturer, contained 10 DM bill acceptors.

Similar to the Tyne and Wear and RATP vendors, the SSB equipment can be programmed to vend a variety of ticket types based on a zone system. In addition, manufacturer representatives indicated that the vendors have the capability to produce stored-value tickets such as those used in the WMATA system.

The coin recycling and microprocessor technology in the Tyne and Wear, RATP, and SSB vendors could enhance unmanned station operation, and improve failure identification, repair productivity, and control of accounting data. When the equipment are connected to a central monitoring facility, the chances for operational improvements are increased.

With a coin recyclying system, the vendors do not have to be regularly filled with coins as do the ICG vendors. Coupled with a high-capacity vault subsystem, this allows for longer periods of service without opening the machine.

The microprocessor technology provides capability in a number of areas: reprogramming of fares, failure indication, and control of accounting data. Reprogramming of fares can be done quickly with the insertion of a new program in the logic. The program can be placed in the machine and sent to trigger fare changes automatically on a given date.

The failure diagnostic capability provides quick indication of the type of failure. This could enhance the productivity of equipment repairs since technicians would not have to spend much time isolating the problem. In addition, failure diagnostics can improve the recording of failures by providing technicians with clearly assignable failure categories.

For the accounting function, the machines can maintain an extensive array of accounting data for long periods, or be programmed to deliver data to a central computer. If the latter capability is utilized, as it is in the RATP system, machine openings can be limited to vault pickups, ticket stock refills, and necessary maintenance actions.

For the first-generation American systems such as ICG and PATCO, the coin recycling and microprocessor technology can enhance system operation and efficiency. However, use of Crouzet vendors such as those in service at Tyne and Wear, requires the use of gates that accept the Edmondson size tickets.

The Tyne and Wear gates are microprocessor-controlled and linked to a central monitoring facility. The gates are used for entry control and are designed to read, write, and cancel.

They incorporate failure diagnostics and a revolving paddle-like barrier. Similar gates in-service at the RATP are configured to read, write, verify and, if necessary, capture. In addition, the RATP gates are linked to either a central or station computer that transmits appropriate commands for gate operation and controls accounting receipts. Many of the 250 RATP gates operate in both directions, similar to gates at PATCO, ICG and WMATA.

APPENDIX A

DESIGN AND OPERATION OF TYNE AND WEAR AFC EQUIPMENT

Passenger-operated vendors installed at Tyne and Wear were designed and manufactured by Crouzet of France, while Cubic Tiltman and Langley, Ltd. built both types of gates (except the ticket readers manufactured by Crouzet). The standard entry gate utilizes a four-section paddle arm barrier to control passenger entry and is fitted with one magnetic ticket reader. The fully accessible gate has a "gate type" barrier and utilizes two magnetic ticket readers to monitor entering and exiting passengers.

The vendor, shown in Figure A-1, incorporates the following characteristics:

- A coin recycling system to provide change to patrons;

- A ticket that is printed and magnetically encoded for visual and automatic control;

- Microprocessor-controlled logic circuits that can be programmed to easily change fares or maintenance procedures;

- A needlepoint printer that allows precision reproduction of essential data;

- Ticket selection capacity of up to 64 ticket types and 128 destinations.

The vendor, as shown in Figure A-2, is comprised of the following major subsystems:

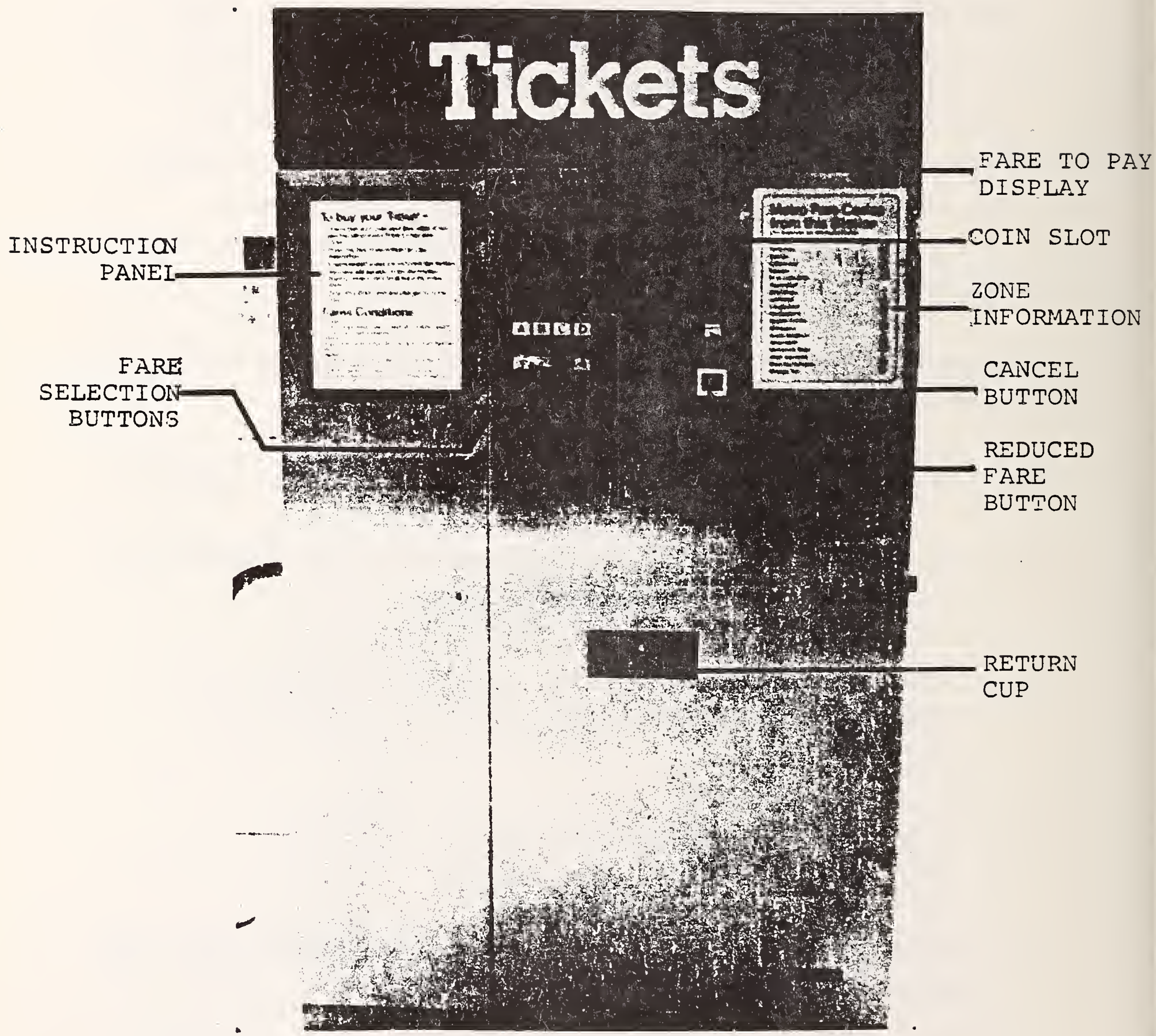

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FIGURE A-1. TYNE AND WEAR VENDOR

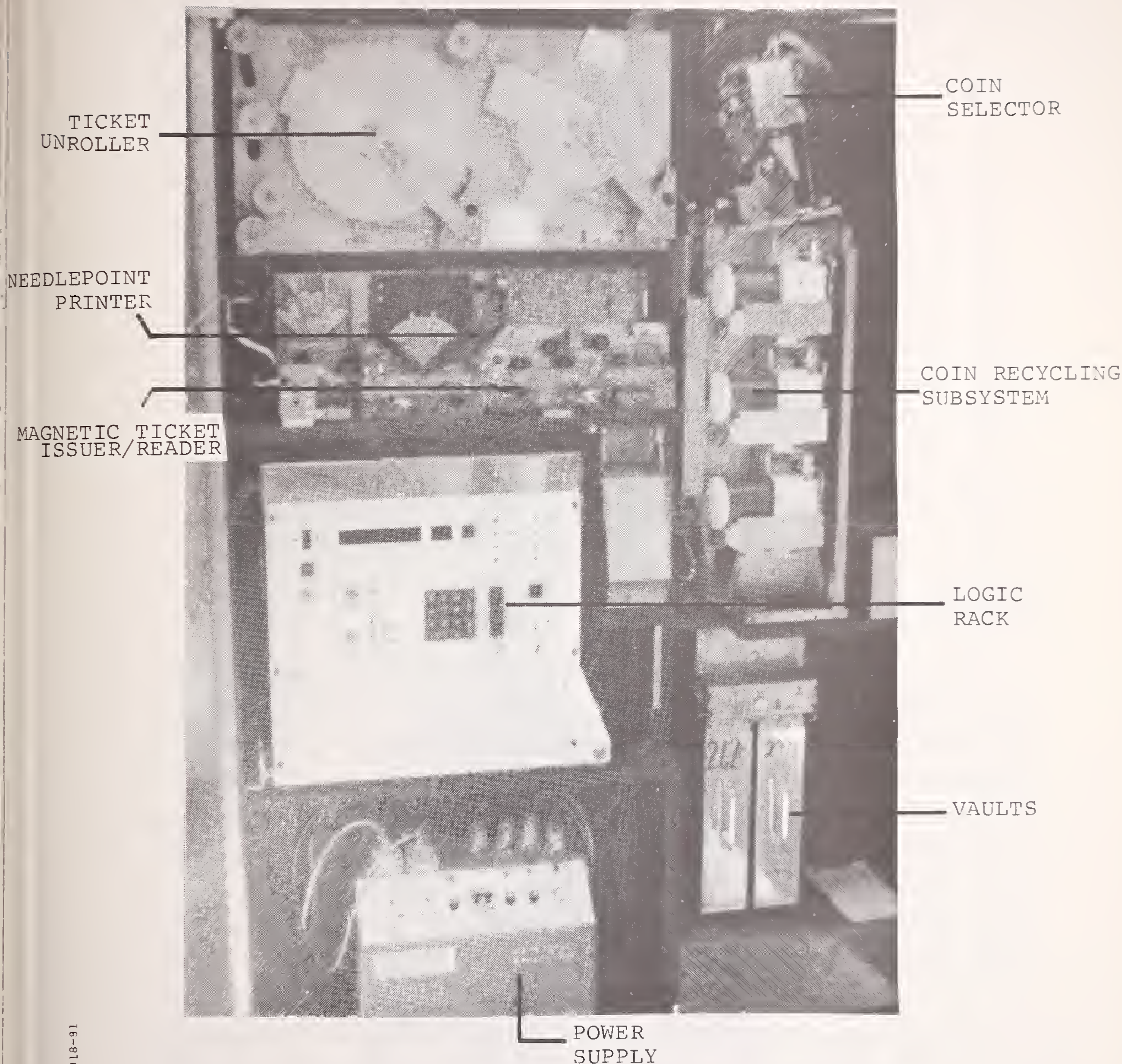

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FIGURE A-2. INTERIOR VIEW OF TYNE AND WEAR VENDOR

- A change-dispensing module that includes the coin selector, the coin-recycling subsystem, and the cash vaults;

- A ticket issuing unit that consists of a ticket roll feed module, ticket printer, encoder, and ticket escrow;

- Logic unit and operating panel including the REPROM (reprogrammable)* microprocessor;

- General power supply;

- Terminal block;

- Heater.

Coin Selector

The coin selector, shown in Figure A-3, has a single slot that closes after each coin is inserted. It will accept up to one coin per second and will check up to 8 types of coins. It verifies coins by comparing their material composition to a "standard" coin located inside the selector and by checking the thickness and diameter of the coin. Coin material is checked electromagnetically to detect slugs. The sequence of operations which occur during the functioning of the coin selector are as follows:

1. Coins are checked for volume and material by passing in front of sensors located along a downward sloping chute.

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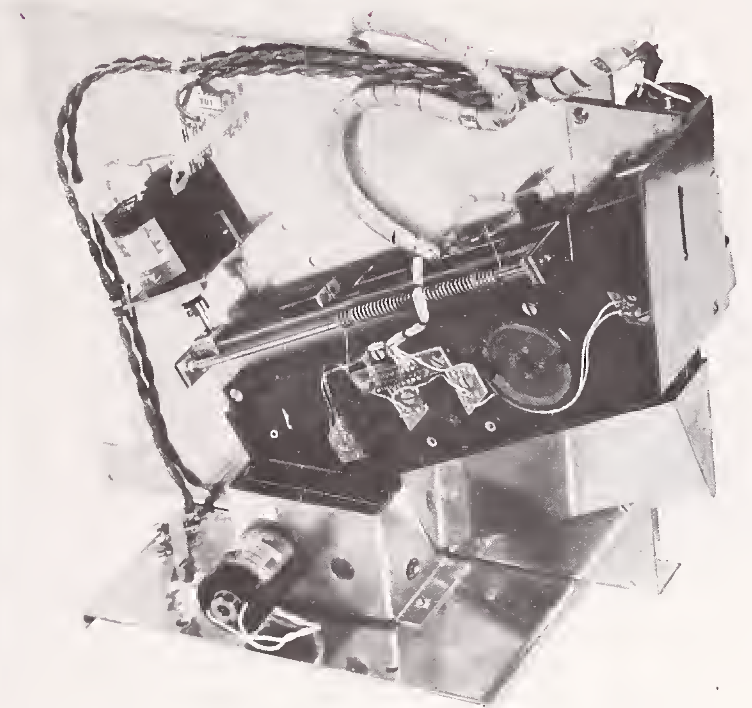
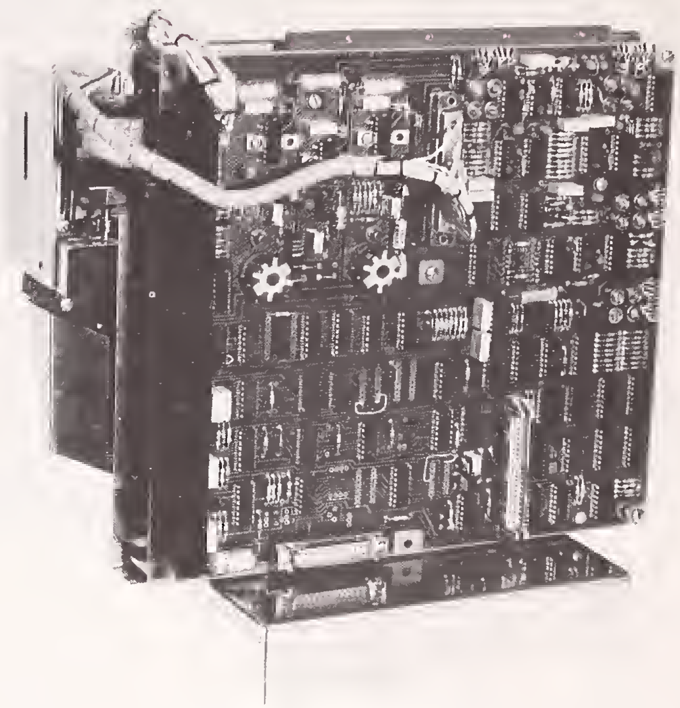
*Appendix G contains a glossary of electronic and computer terms.



SELECTOR -
MECHANICAL SIDE



SELECTOR-ELECTRONIC SIDE

FIGURE A-3. COIN SELECTOR - TYNE AND WEAR VENDOR

2. Bent coins are returned to the customer. If a bent coin becomes lodged in the sensor, an electronically controlled cancelling facility is triggered.

3. Switch points controlled by electromagnets drop good coins into their respective coin drum, or recycler cassette.

Coin Recycling Subsystem

The coin recycling subsystem, shown in Figure A-4, stores coins derived from ticket revenues by coin type and dispenses coins when change is required. In addition, in the event of a cancelled transaction, the subsystem returns the inserted coins to the patron. At Tyne and Wear, there are 6 recycling cassettes that allow change of five different coin denominations (there are two 10P cassettes). Extra coins are directed to one of two vaults.

The recycler consists of two units. The mobile coin cassette rotates on a cradle to which it is coupled. The cradle has a drive motor for the recycling cassette and various sensors. The sensors help the system maintain adequate change-making supplies and prevent overloading of the cassettes.

Three coin slots in the cassette facilitate (1) receiving coins from the selector chute; (2) dispensing coins for change-making; and (3) dropping coins into the cash box when the number of coins exceeds the cassette storage capacity.

The coins are stored inside the cassette in a spiral configuration, leaving the cassette one by one according to the motor rotation. The rate at which coins are accepted into or dispensed from the coin recycler is 0.4 seconds per coin.

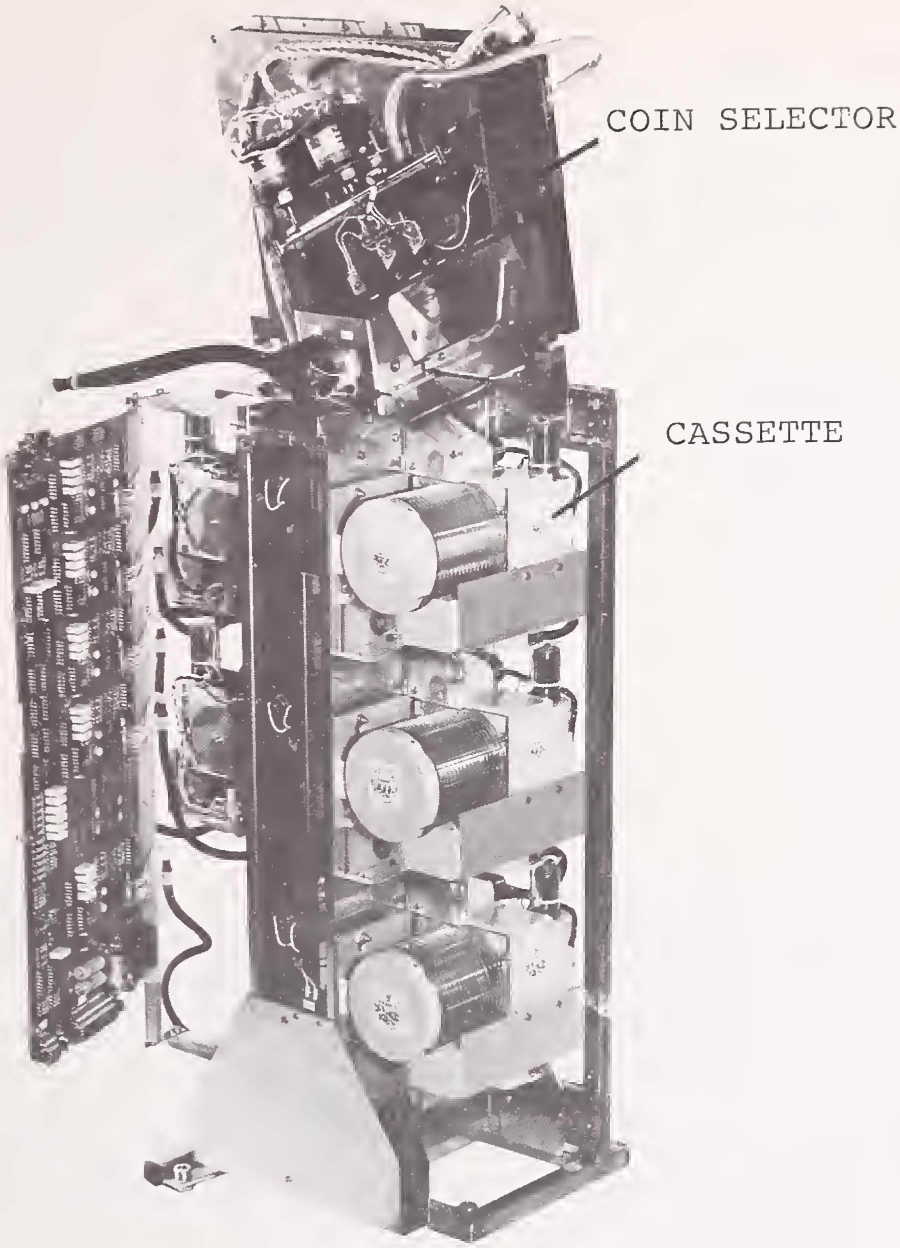


FIGURE A-4. COIN RECYCLING SYSTEM - TYNE AND WEAR VENDOR
(Shown with Coin Selector Attached)

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Logic

Machine logic is controlled by a microprocessor to which the peripheral devices are connected by coupling cards. The CPU card has REPROM memories that contain the program as a whole and memories that have a battery stand-by and contain accounting data. The logic subsystem is housed in a rack, which has a control panel on the front face. The rack is shown in Figures A-5 and A-6. Through this panel, an operator can, among other things, receive accounting data or purchase a test ticket. The panel also serves for maintenance assistance, indicating the code of a failure. There are currently 154 failure codes programmed.

Magnetic Ticket Issuer/Reader

This subsystem, shown in Figure A-7, performs the function of ticket processing, printing, and delivery. The sub-assembly consists of four primary units:

- Unroller (Bulk ticket stock storage roll housing);
- Ticket feeder and cutter (transport/cutting mechansim);
- Needlepoint printer;
- Magnetic reader-encoder.

After the patron has inserted proper fare payment, the REPROM engages the motor drive of the ticket feeder/cutter. One of two paper rolls feeds an appropriate length of ticket stock to the cutter. The ticket is then sent to the printer via pinch and drive rollers. Once printed, the ticket is encoded and verified and dropped into the return cup.

Ticket printing is performed by a programmable needlepoint print unit capable of reproducing any sign or emblem. Encoding of the ticket utilizes a split-phase digital coding technique

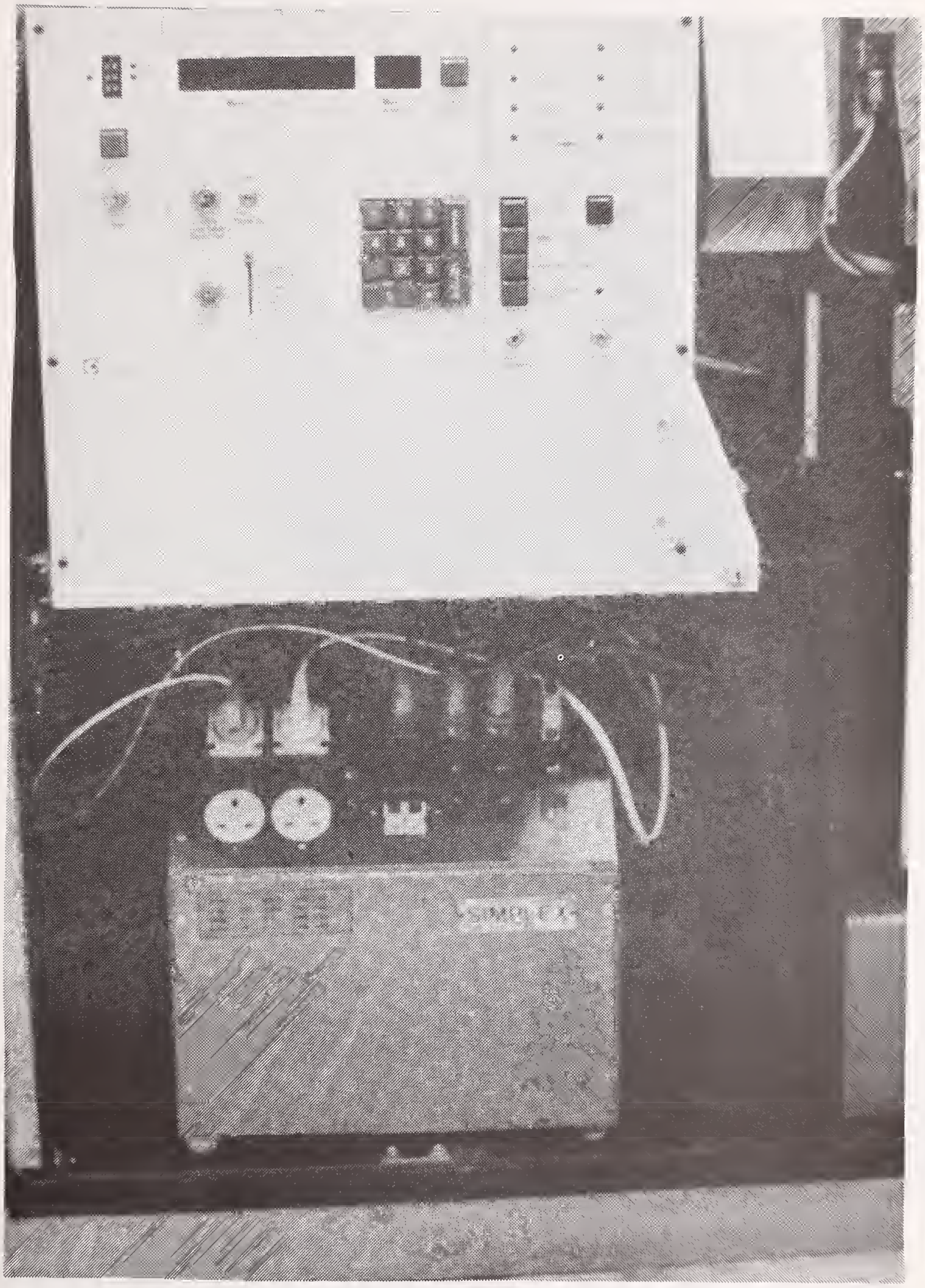

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FIGURE A-5. LOGIC RACK AND POWER SUPPLY - TYNE AND WEAR VENDOR

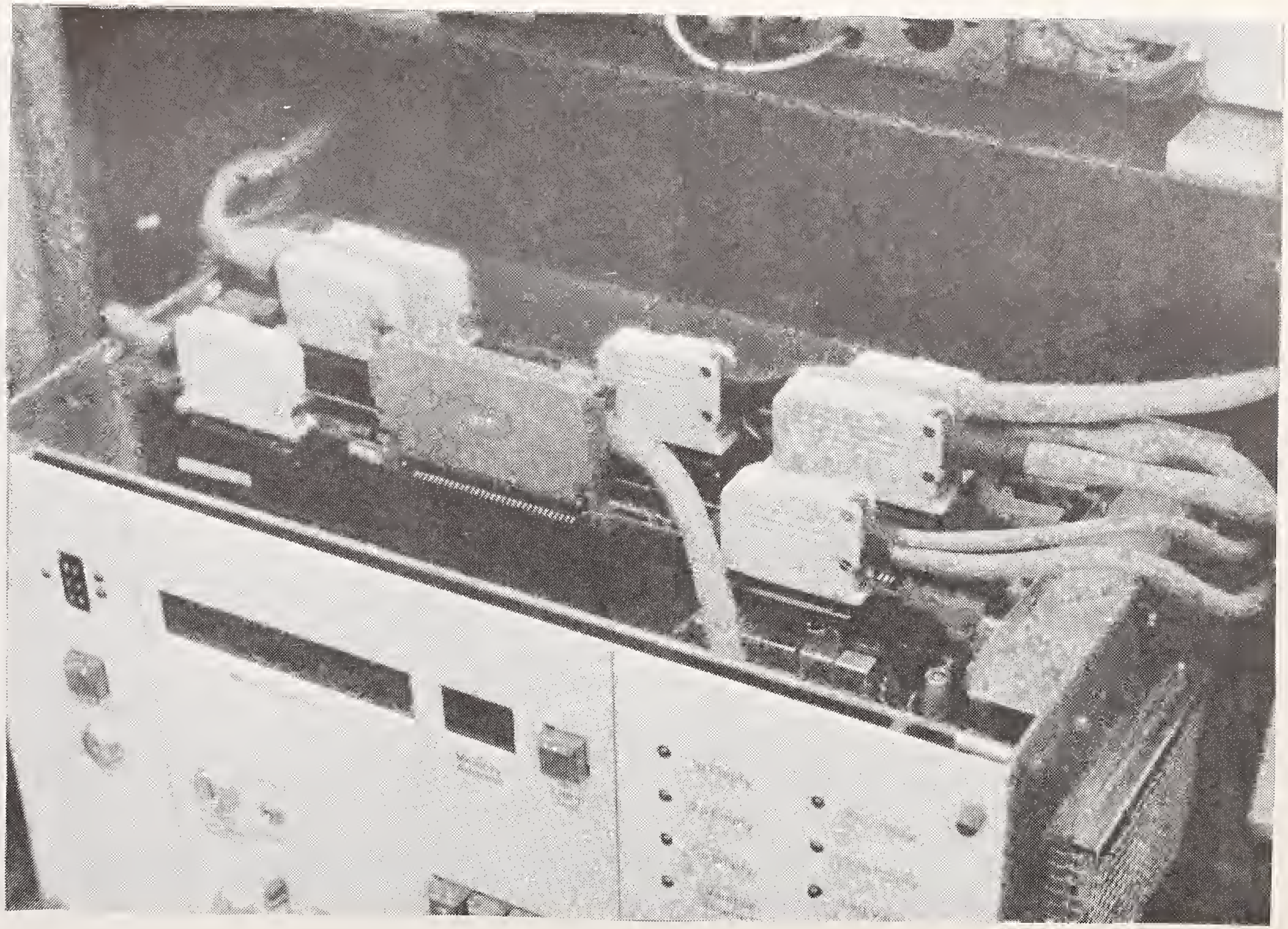

FIGURE A-6. TOP VIEW OF LOGIC RACK - TYNE AND WEAR VENDOR

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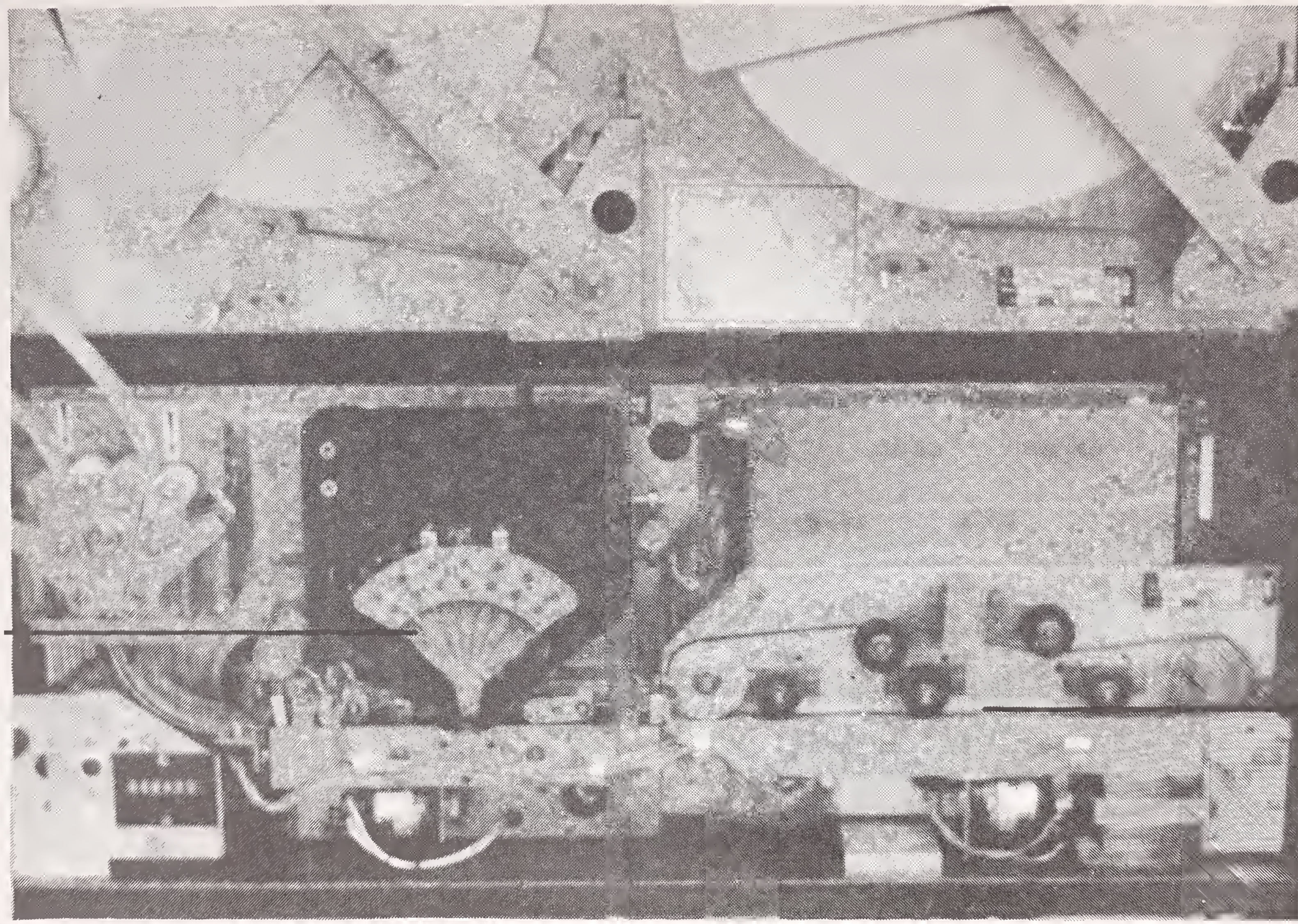

FIGURE A-7. MAGNETIC TICKER ISSUER/READER SUBSYSTEM - TYNE AND WEAR VENDOR

to produce single-ride tickets. Production time of a ticket from the end of the payment to the time it is dispensed is 2.5 seconds.

Power Distribution Subsystem

The power distribution subsystem consists of four major units: a main power supply, a backup power supply, a regulator rack, and a PCB-controlled operating interface.

Vendor operations rely upon a Simplex main power supply, rated at 240 V-50 Hz. The main power supply is shown in Figure A-5. This unit provides 24 to 26 V current output capable of supplying 10 amps (at a peak output of 24 amps) for approximately 10 seconds. This period of time is equivalent to the processing time of one complete ticket issuing cycle including the dispensing of up to twenty coins in change.

Backup power in the event of a main power failure is supplied by a series of batteries. The backup power is sufficient to complete the transaction in process at the time of the failure of the main supply. After this, the machine goes out of service until the main power is restored. However, the backup batteries will continue to supply power to the machine logic for several hours, to ensure that the machine is fully updated to return to service when the main power supply is reinstated.

The regulator rack utilizes switching regulators to provide the necessary five to 18 V power required for the logic subsystem.

Operation of the batteries is controlled by machine logic. In the event of a power failure, the following sequence of actions occurs:

1. An electronic power output sensor detects a significant drop in power;

2. An emergency signal is sent to the logic subsystem 300 milliseconds after power is interrupted;

3. An operating interface switches power supply into the backup (battery) operating mode.

Heater

The vendor incorporates a heater used to maintain a temperature of 5°C inside the machine when the outside temperature drops below -12°C. The heater is comprised of a 500 watt resistor coil, an adjustable thermostat and a fan.

A full list of vendor components follows:

1. Ticket Roll Module
2. Ticket Feed
3. Needlepoint Printer
4. Ticket Feed Back Plate
5. Encoder
6. Encoder printed circuit board (PCB)
7. Coin Selector
8. Coin Selector PCB
9. Change Module Chassis
10. Coin Recycle PCB
11. Cassette Frame
12. Cassettes
13. Vault Frame
14. Vault 1 and 2
15. Power Supply Unit (Simplex)
16. Heating Modules
17. Rack Front Face

18. Rack Front Face PCB
19. Regulating Rack
20. Regulating PCB
21. CPU PCB
22. Ticketing Interface PCB
23. Operating Interface PCB
24. Input/Output PCB
25. Passenger Information Display
26. Selection PCB
27. Memories (on CPU PCB)
28. Passenger Information Display PCB
29. Termination Unit

Automatic Gates

Entry control gates consist of two types, as indicated in Section 2.2.2. Both the standard and fully accessible gate designs incorporate a Cubic-Tiltman Langley housing and barrier subassembly. Crouzet magnetic ticket readers are installed as subassemblies on both gate types. Figure A-8 presents the standard gate and its magnetic reader. Following is a list of the primary components found on both gates:

- CPU Board
- Reader Interface Board
- Memory Extension PCB
- Connecting Board
- Base Plate
- Magnetic Ticket Reader
- Canceller
- Power Supply Unit
- Heating Module
- Memories
- Revolving Four-Section Barrier
- Three Passenger Information Signs

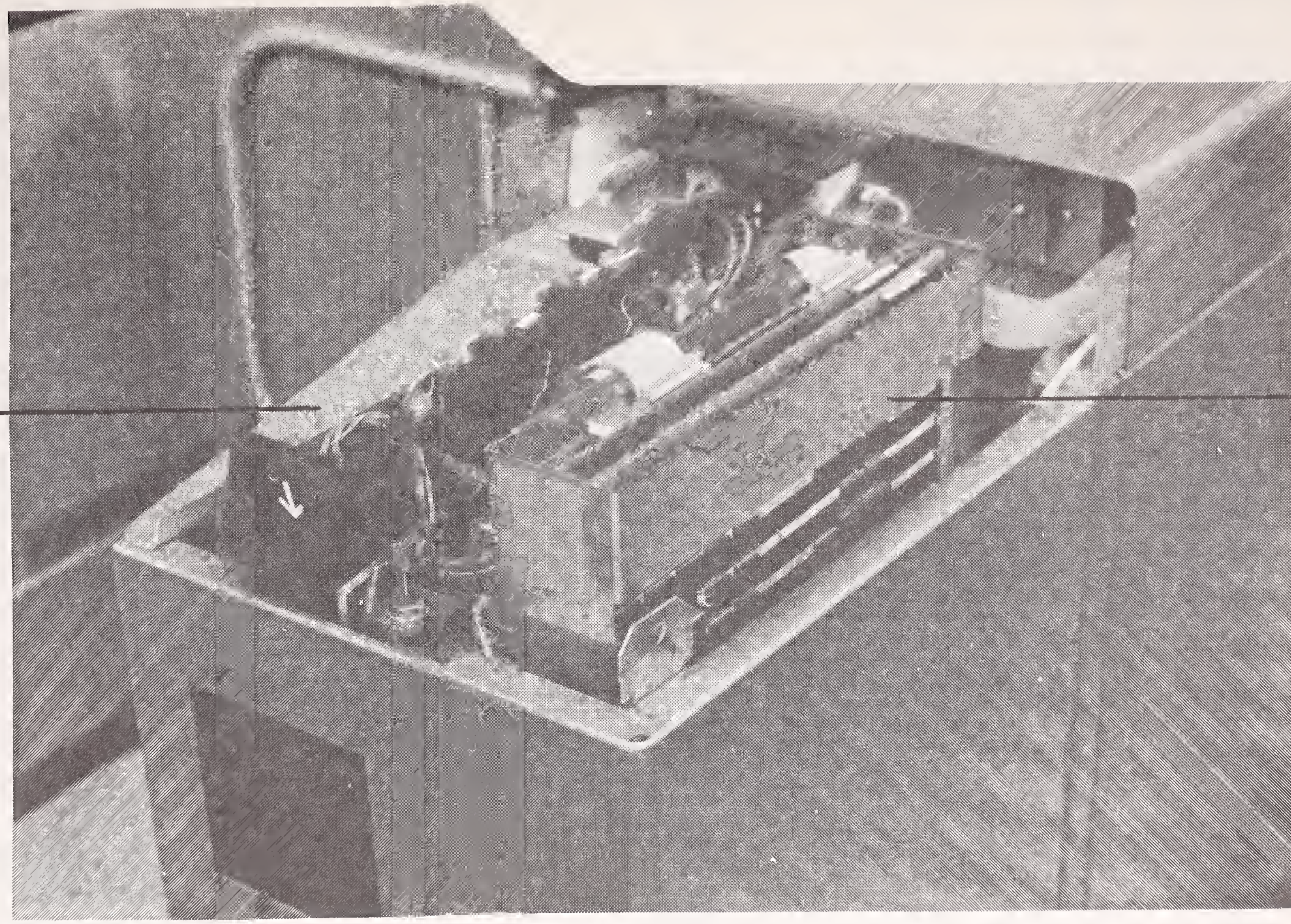

FIGURE A-8. INSIDE VIEW OF TOP FRONT END OF TYNE AND WEAR FULLY-ACCESSIBLE GATE

- "Gate Type" Barrier*
- Indexing Head*
- Modified Reader Interface Board*

Technical information detailing the gate design was available for the magnetic ticket reader only.

Magnetic Ticket Reader

Ticket processing requires approximately 0.6 second. Step one consists of reading the encoded message. The ticket is cancelled if it is a single-ride to indicate that it has been used. Used tickets are returned to the patron for possible visual inspection by a mobile inspector.

Encoding functions are performed by a saturated split-phase type message with a density of 25-50 bits per inch. Data processed by the reader/encoder contain zone, ticket type, validity period and other information.

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*Found only on fully accessible gates.

APPENDIX B
MODIFICATIONS MADE TO TYNE AND WEAR AFC EQUIPMENT

Information provided by Tyne and Wear on modifications made to the equipment since installation is as follows:

Vendors

- Retrofitting of the coin entry slot flap mechanism to prevent sticking;
- Repositioning the vault changeover flap springs to prevent a malfunction;
- Installation of additional ticket guides in the area of the print head to prevent tickets jamming when a new ticket roll is started;
- Reshaping coin selector 'T' springs to prevent coins being routed to the wrong cassette;
- Modifications to coin selectors on certain machines to detect certain foreign coins (100 Lira) and football tokens;
- Replacement of the ticket escrow microswitch with a more durable unit.

Gates

No modifications have been carried out on the ticket transporters since their installation.

APPENDIX C

TYNE AND WEAR AFC MAINTENANCE

Crouzet provided a set of recommended preventive maintenance measures applicable to the Tyne and Wear AFC equipment. These procedures represent a standardized approach to normal preventive maintenance.

The specific steps taken by Metro maintenance personnel are also provided below. Each machine receives preventive maintenance about every six weeks.

Preventive Measures Recommended by Manufacturer

- Entry/Exit Gates

  Every 4-6 weeks (dependent upon passenger traffic), gates should be thoroughly cleaned; and belts visually inspected for wear, and adjusted, if necessary. Heads should be inspected and adjusted; output levels of optical detectors that determine ticket positioning should be inspected and adjusted if necessary. On the average, these actions should be accomplished by technical personnel in one hour or less.

  Once a year, the magnetic ticket issuer/reader subsystem should undergo a general overhaul. Included in this task are a major cleaning, adjustment and lubrication, as well as checking for, and replacement of worn parts.

- Vendors

  Every two months, the ticket encoder and printer unit should be cleaned, belts visually inspected; display

panel, light bulbs, and operation of coin recycling cassettes checked. In addition, the processor should be checked through the test mode. On the average, these measures should be accomplished in 2-3 hours.

In addition to the two-month maintenance action, each vendor should have a general shop inspection and overhaul after 400,000 tickets have been issued.

Preventive Maintenance Procedures Undertaken by Tyne and Wear

The following are the steps undertaken by Metro AFC maintenance personnel when preventively maintaining the vendors and gates. Note that the vendor is referred to as a ticket issuing machine (TIM).

ROUTINE MAINTENANCE PROCEDURE
TICKET ISSUING MACHINE

NOTE: If in any doubt, consult the TIM Operating and Maintenance Manuals.

Before commencing, check through intervention sheets for unusual or recurring fault problems.

1. Check the machine is in service;

2. Test all push buttons;

3. Check passenger information display is correct;

4. Check the position of the selector slot;

5. Press on the doors to test efficiency of the door stop;

6. Check the general condition of paint and signing;

7. Open the doors - they should open without difficulty or excessive effort;

8. Take and retain - Cash total ticket,
   - Ticket total ticket,
   - Cassettes contents ticket;

9. General cleaning of the cabinet, remove all used tickets, dirt and debris;

10. Visual check of the ticketing unit;

11. Clean the ticket feed and cutter;

12. Test the correction function of the ticket feed, clutches. Check paper can move without difficulty;

13. Check the cutter cuts paper correctly (no burrs);

14. Clean the printer unit, sensors, needle head and ticket transfer route;

15. Check the position of the sensors, test the voltages. Check the sensor fixings are locked with varnish;

16. Check that ticket transfers manually through the printer;

17. Check the length of tickets and the quality of printing;

18. Empty the chopped ticket chute. Note and analyze the number of cut tickets;

19. Clean the encoder unit, pinch rollers, heads, sensor using methanol;

20. Check the position of the S6 microswitch;

21. Check the smooth running of the ticketing unit and make sure the destruction module cuts properly;

22. Test the escrow flap;

23. Make 100 test tickets of mixed types, checking for defects;

24. Test the efficiency of the unrolling unit springs;

25. Check the microswitches on the unrolling module work correctly;

26. Test the efficiency of the batteries by switching off during ticket printing and leave switched off;

27. Unlock the change giving unit, check the smooth movement on rails, no contact with the vault frame. Check the correct position of the change giving unit on the bracket at the back of the cabinet;

28. Clean the selector, especially where the coins transfer and 'valid coin' switchings. Check the mechanical functions (switching flaps, etc.);

29. Remove the coin selector;

30. Check the 'T' springs and the flaps for correct and smooth opening and closing;

31. Check that the chute plates are parallel and that the mobile one is well against the fixed part;

32. Put the selector back in position;

33. Check the cassette cam position;

34. Push back the change giving unit and lock it;

35. Check vault frame flap for correct operation at 16V and make sure the vault flap detection microswitches are correctly positioned;

36. On the power supply, check the value of all fuses;

37. Clean the fan filters on the electronic rack;

38. Check that all plugs are well in position and that the electronic rack is in good condition;

39. Switch the machine on;

40. Check the time and date ('memory contents' 17 and 18);

41. Test the lamps on the front panel on the electronic rack;

42. Check remote control signals (except vault full) - verify with Station Controller. (PAX 2126);

43. Check the display bulbs using 'memory contents' - 85 to 88;

44. Note printer electromechanical counter value =;

45. Note 'memory contents' 02 =
03 =
10 =
11 =
12 =
13 =
14 =

46. Close the doors;

47. Check that the intervention has been monitored by the Control Centre and note maintenance visit on intervention sheet;

48. Note any comments on check sheet. Continue on rear of sheet if necessary.

ROUTINE MAINTENANCE PROCEDURES
TICKET TRANSPORTER

NOTE: If in any doubt, consult the transporter Operating or Maintenance Manual.

Before commencing, check the intervention sheets for recurring or unusual fault patterns.

1. Check that the machine is in service;

2. Carry out mechanical maintenance procedure;

3. Check the position of the transporter in the barrier cut outs;

4. Remove the barrier lid, open the barrier - note any difficulty with the locks;

5. Visual check of the transporter for defects;

6. Open the transporter and clean it using a clean rag soaked in methanol;

7. Check the pinch rollers, belts and heads are in good condition;

8. Close the transporter;

9. Check the gap is correct between the heads and rollers with a feeler gauge;

10. Switch power off;

11. Remove the transporter;

12. Clean the base plate;

13. Put the transporter back in position;

14. For handicapped channels, repeat operations 5 to 14 on the exit side;

15. Clean the power supply and remove all tickets and debris from the floor of the barrier;

16. Check all fuse values;

17. Switch power on;

18. Check transporter memory by stepping through positions 1 - 7 on function thumbwheel;

19. Step through automatic test function by setting function thumbwheel to 'F' and pressing push button;

20. Replace any burnt out lamps;

21. Reset the machine and leave thumbwheels set to F 00 (normal transporter) F 01 (Handicapped);

22. Check that the remote control signals/controls operate satisfactorily (Check with PAX 2126);

23. Close and lock the barrier then check barrier operation, cancellation and overprinting using a valid TIM ticket;

24. Note maintenance visit on an intervention sheet;

25. Note any comments on the check sheet.

APPENDIX D

DESIGN AND OPERATION OF SSB TICKET VENDOR

The Autelca Model B-28/RSN ticket vendor used at SSB, incorporates recent technological advances in its design and construction. In addition, the large number of selector buttons available and microprocessor logic provide the transit property with a high degree of flexibility in establishing fare policy. The principal features of this machine, shown in Figure D-1, are:

1. An electronic and mechanical coin verifier that has the capability to accept up to six different coin denominations through a single coin acceptor slot;

2. A front face panel design that allows up to 40 tariff selector pushbuttons, 28 of which are in service at the SSB;

3. A machine logic subsystem, controlled by reprogrammable microprocessors enabling data memory and storage for 12 months of continuous operation;

4. A needlepoint printer that permits flexibility in printing ticket data;

5. A capability to produce two ticket types. Single and multi-ride tickets are vended at SSB;

6. A capability to reprogram data printed on tickets;

7. Recording and display of failure diagnostic data;

8. A cash control system via locked security vaults.

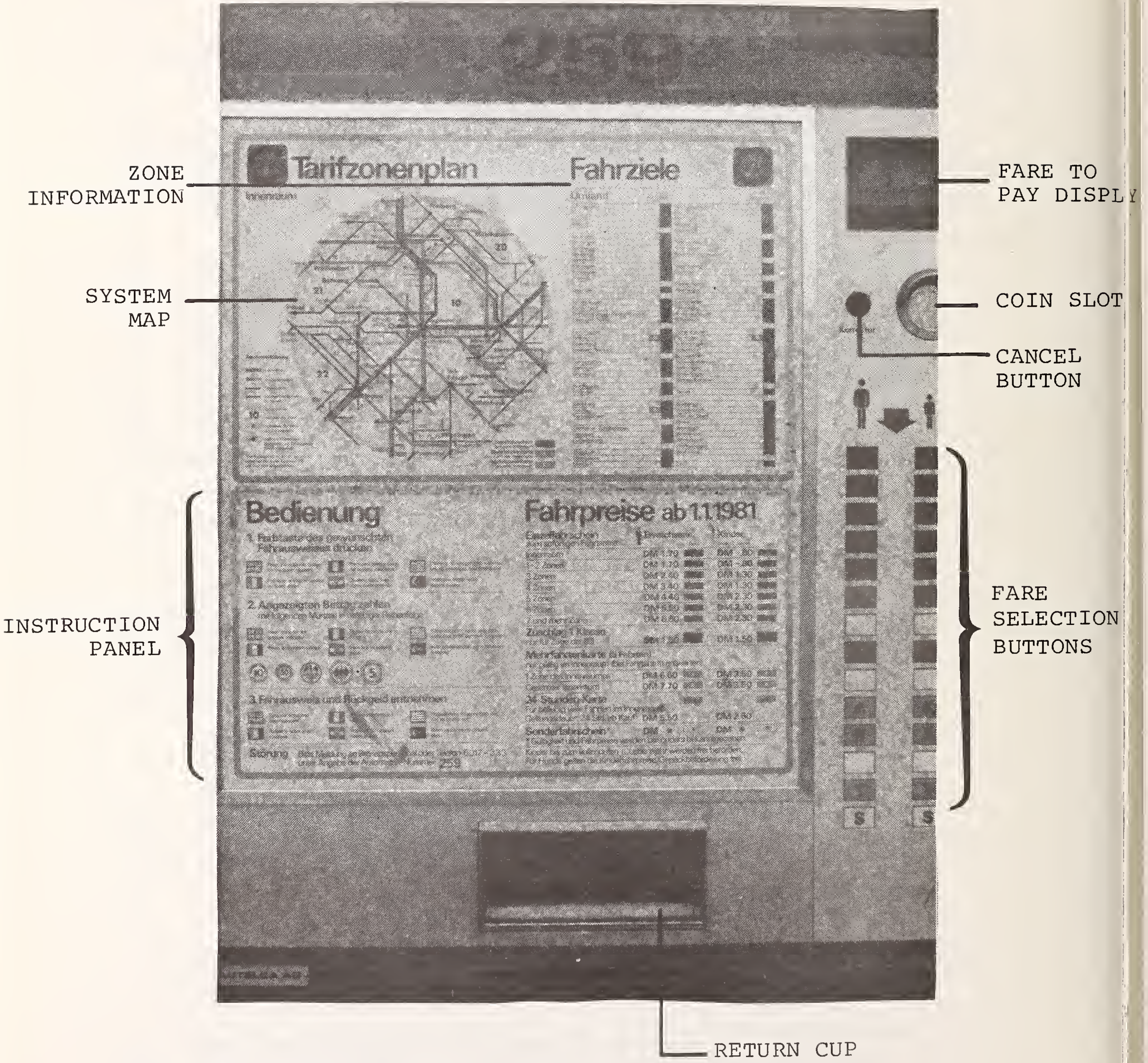

FIGURE D-1. SSB VENDOR

The vendor, as shown in Figure D-2, is comprised of the following major subsystems:

1. A coin selector subsystem that accepts five coin denominations and electronically and mechanically checks each coin for size and material;

2. A coin recycling subsystem that includes a coin escrow;

3. A vertical sprocket ticket feeder with a storage capacity of approximately 10,000 single-journey tickets;

4. A needlepoint printer that includes a self-sharpening cutter and a quartz crystal clock to keep accurate time for printing of ticket data;

5. A machine logic subsystem controlled by rack-mounted, modular printed circuit boards and a reprogrammable microprocessor. Included is a data registration and calculating unit that records statistical data and facilitates a printout of these data;

6. A main power supply equipped for 220-volt AC operation. The unit also houses an autonomous rechargable battery in the event of a power failure;

7. A coin cash box with an automatic vault-locking device that can only be opened by authorized personnel.

Coin Selector

The Autelca coin selector accepts coins through a single slot located in the upper right of the front face panel

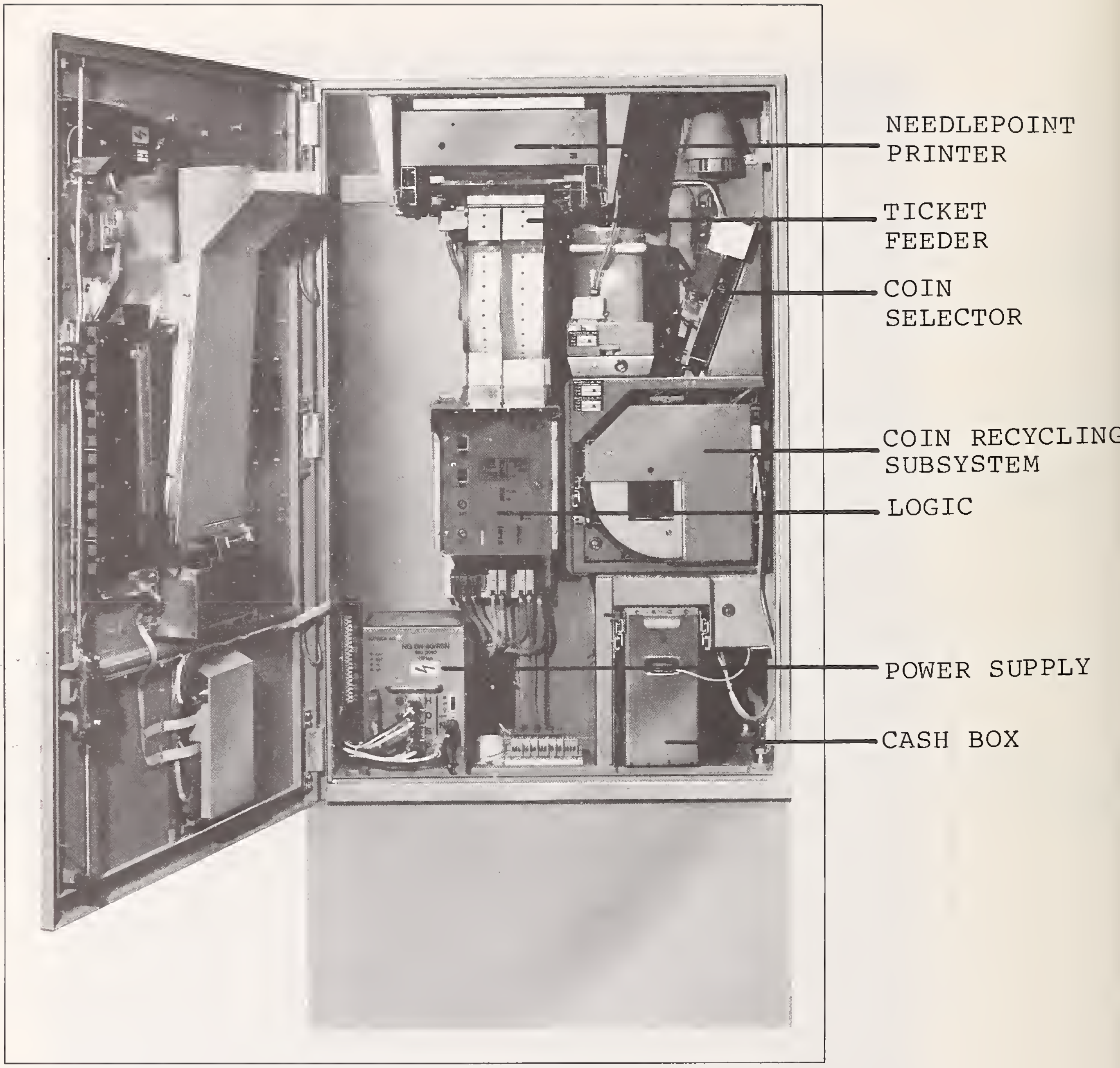

FIGURE D-2. INTERIOR VIEW OF SSB VENDOR

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(Figure D-1). The selector, shown in Figure D-3, accepts five coin denominations and has the capability to accept a sixth coin. The selector receives, tests, accepts or rejects coins. In addition, it sorts coins and directs them to their corresponding recycling coin storage disc. The selector automatically rejects foreign materials, such as clips, matches and washers, that would ordinarily damage the machine. These foreign articles drop directly to the coin return cup.

A Light Emitting Diode (LED) displays the proper fare to be paid by the passenger after the desired zone and ticket type buttons on the display panel have been selected. Coins can only be inserted into the slot individually. After each coin is inserted, the slot closes briefly to allow the selector to verify and process the coin. A mechanical verifier checks accurate weight and size, and an electronic sensor checks the incoming coin against a model coin to determine whether it contains the correct alloy material.

Once the coin is accepted, it drops down a coin guiding plate to its appropriate coin storage disc. The coin guiding plate consists of six channels, one for each coin type. The plate is perpendicular to the main selector channel and angled approximately 45^{o} to the ground. The channel for the largest coin is furthest away from the outside of the machine. This design facilitates coin sorting. After dropping through the appropriate channel, the coin falls into a waiting slot in the rotating coin storage disc. Each disc has a holding capacity of 120-200 coins, depending upon coin size.

<u>Coin Recycling Subsystem</u>

The recycling unit is designed to perform four primary functions: (1) accept coins from the selector into one or more of the five operating coin storage recycling discs to maintain

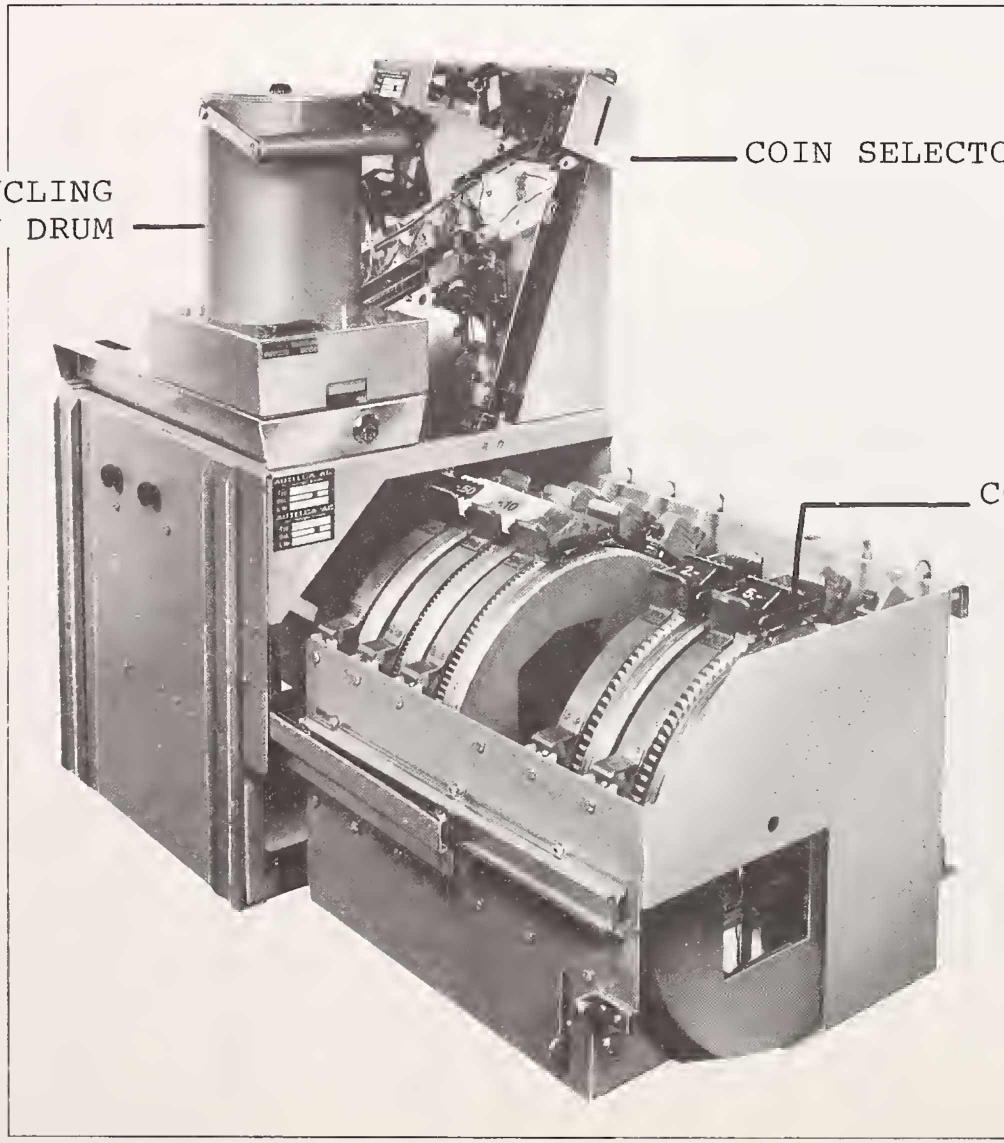

FIGURE D-3. RECYCLING SUBSYSTEM - SSB VENDOR (Showing coin Selector and Nonrecycling Coin Drum)

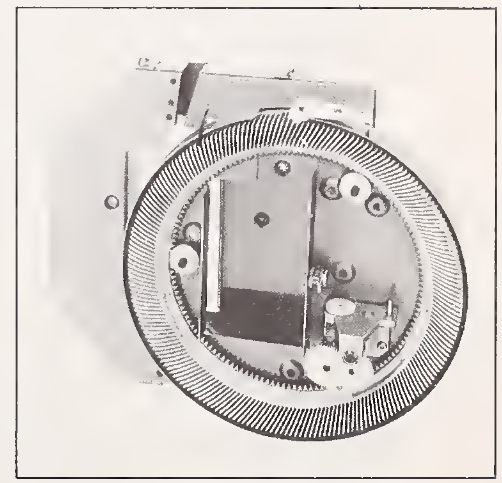

FIGURE D-4. RECYCLING COIN DISC - SSB VENDOR (Rear View)

adequate coin supply, (2) hold coins in escrow until the patron's transaction is completed or cancelled, (3) drop coins into the cash vault when the disc is at capacity, and (4) provide change. The subsystem is shown in Figures D-3 and D-4. Note that the figure includes the coin selector and an optional nonrecycling coin drum described below.

Each of the five coin discs acts as an escrow unit until the transaction is completed. Inserted coins drop down the coin guiding plate into the disc. If the transaction is cancelled, the disc rotates counterclockwise until aligned with a slot on the left side of the subsystem housing. The slot then opens and the coin drops through a chute to the return cup.

In like manner, the coin disc returns change by rotating counterclockwise and releasing a coin into the chute to the return cup. If more that one coin is to be returned from the same disc, it rotates the required number of times. An algorithm in the logic assures that change is given using the the largest coin denominations possible.

When one of the recycling discs reaches its capacity for coin storage, the disc releases a coin into the cash vault prior to accceptance of an inserted coin. This overflow feature is accomplished by rotating the disc clockwise until the cash vault slot is reached on the right side of the disc housing. The slot opens and the coin drops through a chute to the vault.

In order to maintain a sufficient supply of coins for change-making, the coin recycling subsystem was designed to include a maximum of two 10 pfennig nonrecycling reserve coin drums. Each drum has a capacity of 1,000 coins. Depending on ticket volume, vendors can be equipped with either one or two drums. The majority of the machines do not contain the supplemental coin drums.

The SSB ticket vendors that do not contain reserve drums will not dispense change when the number of coins in any one of the five disc storage units falls below a pre-set minimum. Patrons are alerted by an illuminated sign located on the front display panel that reads, "No Coin Return, Insert Exact Amount".

For the vendors with the units, the drums are periodically refilled on a fixed schedule. Coins are housed within the unit in several vertical stacks. If coins in the 10 pfennig recycling disc fall below the minimum acceptable level, the subsystem automatically switches into reserve drum operation. The drum continues to operate until the coin reserve is sufficiently replenished. In machines equipped with two drums, the second is actuated upon depletion of the first. If only one drum exists and supply is depleted, the vendor will switch into normal disc operation.

Ticket Feeder

Form printed tickets are produced from fanfolded ticket stock. The vendor is equipped with two vertical feed stacks. Single-ride ticket stock is 30MM wide and 76MM long when cut. Multi-ride ticket stock is 60MM wide and 120MM long. The ticket stock is manufactured with 6MM perforations along its center. These perforations permit the sprocket drive to move the paper past the needlepoint printer to the cutting device. Processed tickets then drop through a gravity chute to the patron. The single-ride paper stack has a capacity of 10,000 tickets. The multi-ride storage stack has a capacity of 2,400 tickets.

Needlepoint Printer

The needlepoint printer, shown in Figure D-5, operates at a speed of 200 characters per second using a mosaic printing technique. The printer is controlled by a microprocessor logic subsystem that generates instantaneous commands during ticket processing. In addition, the printer uses a single color, self-reversing ribbon. Imprinted data can be modified by altering the software program of the microprocessor. Periodic reprogramming of the needle printer can be done to alternate between various negative or positive security imprints, thereby minimizing fraud.

Ticket printing is coordinated by the vertical sprocket feeder allowing for precise line by line printing. Once printing is complete, the ticket is cut by a self-sharpening knife. The ticket then drops through a gravity chute to the return cup.

Both ticket types and the printed data are shown in Figure D-6. A single ride ticket includes the following data (from left to right):

- Zone number (three characters);
- Station ID (three characters);
- Machine ID (three characters);
- Date (month and day - four characters);
- Time (four characters based on continuous 24-hour clock);
- Ticket serial number (one character);
- Fare paid (four characters).

The multi-ride tickets use a modified data format consisting of two horizontal lines of data. The top line contains (from left to right):

FIGURE D-5. NEEDLEPOINT PRINTER SUBSYSTEM - SSB VENDOR
(Turned 90° - Bottom Facing Out)

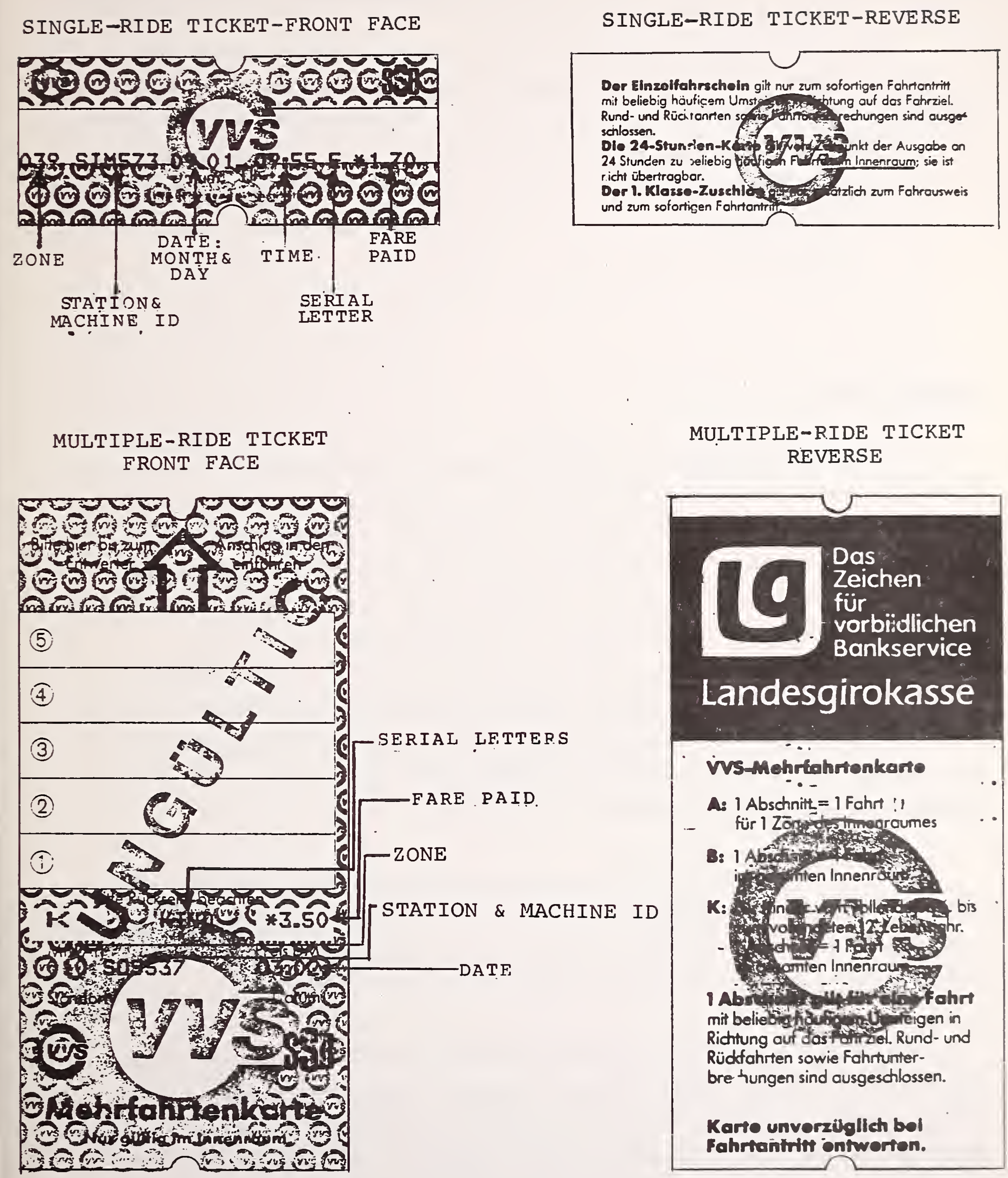

FIGURE D-6. SSB VENDOR TICKETS

- Ticket serial number (three characters);
- Fare paid (four characters).

The bottom line contains four of the items printed on the single-ride ticket:

- Zone number;
- Station ID;
- Machine ID;
- Date.

Machine Logic

All machine commands, calculations, and data registration functions are controlled by the logic subsystem. Primary hardware consists of vertical rack-mounted, printed circuit (PC) boards containing random access memories and a reprogrammable microprocessor. The PC boards slide out to permit modularized access in the event of an electronic failure.

The main component of the logic system consists of a reprogrammable microprocessor responsible for all decisions, corresponding orders, necessary calculations (such as change-making) and diagnostic functions.

The logic contains a fare calculator that can compute fares from a minimum of .01DM to a maximum of 99.99DM (or any other currency using the decimal system). The logic also contains a price tariff memory that can store up to 28 fares.

Statistical data are registered and stored in memory. The data include total cash receipts during a one-year cycle, overpayments, number of tickets sold at each fare level, machine number and a running audit figure. The memory unit is completely enclosed to maximize safety. It may be lead-sealed for security purposes.

Power Distribution Subsystem

The power distribution subsystem, i.e., power supply, on the SSB B-28/RS machines is designed for 220-volt, 50Hz single-phase, alternating current supply. However, the main power supply system may be adapted to 110-volt requirements. The B-28/RS power distributor stabilizes power fluctuations within the following voltage variations: long term voltage must not drop below 10 percent or rise above 15 percent, permitting a range of 187-242 volts alternating current (AC). Short-term power fluctuations of up to one second may surge to 20 percent or drop 15 percent below specifications, permitting a range of 187-264 volts AC. Trigger threshold is 30 milliamps in the event of leakage by grounding. In the event of a power failure, a rechargeable battery is available for up to 135 hours of service.

Coin Cash Box

The SSB cash box locks automatically when removed to prevent service personnel from accessing the cash. The automatic locking device is disengaged only when the cover of a replacement cash vault is installed.

APPENDIX E
MODIFICATIONS MADE TO SSB TICKET VENDOR

Since installation, SSB has modified the vendors as follows:

1. Changed software in the CPU PC board because the printer speed was not consistent, resulting in tickets being cut to the wrong size. This modification was done soon after installation.

2. Changed the material and design of the coin guiding plate between the selector and the discs. The hard plastic material was cracking and the straight channel design allowed dirt to accumulate. Softer plastic material was installed and a new zig-zag design on the plate prevented dirt accumulation.

3. Installed a modification on the 5DM and 2DM coin discs. The modification was designed to nudge the disc just before a coin was to be released to the vault or to the return cup for change. This modification was installed because dirt accumulation on coins sometimes resulted in their sticking and not releasing from the disc.

SSB is currently making modifications to the coin selector. A small magnet is being installed near the insertion slot in order to check for slugs. In addition, a sensor is being installed to check for a grooved edge on inserted objects.

APPENDIX F
SSB AFC MAINTENANCE

As indicated in Section 6.4, all major ticket vendor subsystems are regularly replaced and brought to the shop as part of a fixed preventive maintenance plan. The frequency of the adjustments, overhauls, and/or cleanings required range from a six-month to a one-year interval, depending upon equipment use. Based upon interviews with AFC service technicians, the following component-specific preventive maintenance practices were derived.

Needlepoint Printer

The needlepoint printer, which is one of the most sensitive components in the vendor, is removed and serviced at least once a year. In the shop, the entire unit is degreased with an acid-based solution. All mechanical interfaces are then oiled and greased. Lubricants are applied sparingly to keep them from leaking into unwanted areas. Electrical components are then cleaned with a brush. Electrical parts, such as transistors are tested with a voltmeter. Voltage output which falls below specifications indicates a need for parts replacement while voltage above specifications is adjusted. The needle of the printer and related parts are cleaned and checked for proper operation.

Coin Selector

A single shop technician is assigned to maintenance of all coin selectors. They are serviced at least once a year. During servicing, selectors undergo a thorough cleaning and degreasing of all mechanical parts. Electrical components are tested to determine whether they meet specifications. Failure to pass

electrical tests means replacement or adjustment of the part in question.

Recycling Coin Storage Disc

Each disc is serviced once a year. Servicing includes cleaning and testing of electrical components such as the motor that powers the rotation of the disc. Due to the irregular design of each disc, they are cleaned utilizing ultrasonic techniques.

Non-Recycling Coin Storage Drum

Drums are also cleaned and tested for proper electrical functioning once a year.

Cash Vault

No maintenance is required.

APPENDIX G
GLOSSARY OF ELECTRONIC TERMS

REPROM — Acronym for Reprogrammable Read-Only Memory. It stands for any memory which is not programmed during its fabrication and requires a physical operation to program it. The REPROM is distinct from a PROM in that its memory banks can be cleared using ultra-violet light.

CPU — Central Processing Unit. It is the central processor of all machine logic functions. It contains the main storage, arithmetic unit, and special register groups.

PCB — Printed Circuit Board. Refers to an electronic device containing resistors, capacitors, diodes, transistors, and other circuit elements which are mounted on cards and interconnected by conductor deposits.

APPENDIX H
REPORT OF NEW TECHNOLOGY

The work performed under this contract has examined the performance of automatic fare collection equipment at three European properties. Each operates equipment that incorporates new technology - microprocessors, needleprinters and automatic coin recyclers. The results of the study indicated that the overall reliability of such equipment was significantly better than similar equipment that does not incorporate the devices. In addition, the report suggests that use of such equipment could enhance operation of AFC systems at U.S. transit properties.

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